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GOVERNMENT OF MADRAS

X APRIL—JUNE 1955 No. 1

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OF THE ELECTRICITY DEPARTMENT GOVERNMENT OF MADRAS

VOL. X APRIL—JUNE 1955 No. 1

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20 DEC 1955
MAD

The Periyar Hydro-Electric Scheme

By V. P. APPADURAI, B.A., M.I.E. (Ind.),
Chief Engineer for Electricity.

(*This article is reproduced from " Madras Information ", March* 1955.)

THE PERIYAR Hydro-electric Scheme was inaugurated on 11th February 1955, by Sri K. Kamaraj Nadar, Chief Minister. The scheme when completed will be a major contribution to the Madras Grid, generating 140,000 KW from June to March and 37,000 KW from March to June.

The Periyar river has its origin near Kallimalai—a peak on the ridge between Travancore State and Sankaranayinarkoil taluk on the Madras side. For the first 16 miles the river cuts its way through the hills, covered with virgin forests, in a northerly direction. About three or four miles below Thanikudi, (where a forest rest-house is in existence) it takes a turn to the west and flows for about eight miles, where it was dammed 60 years ago, in 1893. Below the dam site, the river flows generally in a north-westerly direction and finally empties itself into the Arabian Sea near Cranganur.

The total length of the river is about 130 miles, the catchment area above the dam 239 square miles and the average annual rainfall, in this catchment, about 100 inches. From the early part of the nineteenth century, engineers were contemplating the diversion of the Periyar waters, which were practically going to waste, into the Cumbam Valley in Madurai district for irrigation purposes. It was left to Col. Pennyquick and his band of engineers to initiate the project and complete it in 1893.

50 Years of Irrigation

The Periyar waters have been irrigating a vast stretch of land in the Madurai district for more than half a century. The Periyar Irrigation Project is a unique one for two reasons. A river which was flowing west and wasting itself into the Arabian Sea was dammed and the waters turned into the Vaigai basin through a tunnel bored through the dividing ridge, whereby about 1½ lakhs acres of land receive the benefit of irrigation. Secondly, the river which was flowing in our neighbouring State of Travancore-Cochin without benefit to anyone, was harnessed and used for raising food-crops in Madurai district in our State of Madras—thus paving the way for inter-state co-operation from the 19th century itself.

It was in the year 1886 (during the British regime) that an agreement was entered into between the Maharaja of Travancore and the Secretary of State for India, wherein the rights to use the Periyar waters for irrigation were conceded by the Travancore State to the Madras

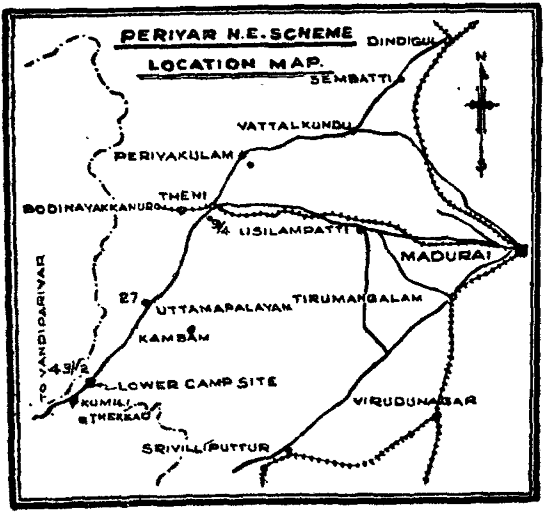
State for a period of 999 years on the payment of an agreed sum annually.

The Periyar waters cascade over a fall of more than a thousand feet before reaching the plains, thus wasting a lot of potential energy, on the way, which could be harnessed for useful purposes. This aspect has been engaging the attention of the engineers from the very beginning of the Periyar Irrigation Project. The main difficulty with the development of hydro-electric power from the Periyar waters is that power could not be developed during the non-irrigation period, i.e., from middle of February to early June. On this account, the Periyar Hydro-electric Scheme has been proving unattractive for a very long time.

Award in Favour of Travancore

Also, the scheme could not be proceeded with as the Travancore Government objected to the development of power from the Periyar waters as the lease deed did not provide for the same. The matter was taken up for arbitration in the years 1936–37 and as the arbitrators gave differing awards it was referred to an umpire in the year 1941, who gave the award in favour of Travancore.

After the advent of Independence in 1947, and when popular Ministries were functioning in both the States, representatives of the two Governments met at Trivandrum on 15th June 1949 and came to an agreement regarding the terms of additional royalty to be paid by the Madras State to Travancore-Cochin for the generation of power. Thi agreement was not ratified by the Travancore-Cochin Government Subsequently, there were politica changes on both sides of the borde due to the general elections in 1952, and the stale-mate continued.



Scope of Scheme Revised

In the meanwhil the scope of th Periyar Hydro-electri Scheme required revi sion, due to the proposed construction of the Vaigai Reservoir. which could be usec for storing the tail rac discharge from th power station during the non-irrigation period to be subsequently used for irrigation. By judicious regulation of the Periyar Lake and the proposed Vaigai

Reservoir, it is estimated that the minimum power draft can be increased from 50 cusecs to 300 cusecs.

The growing demand for power in the State required that the Periyar Hydro-electric Scheme should be included in the First Five-Year Plan and as no time could be lost, the old scheme was revised providing for utilising the maximum discharge from the Periyar Lake, and submitted to Government. Further field investigations were continued to see whether the scheme could be improved. The Scheme is for the installation of three generating sets of 35 M.W. each in the first stage to be subsequently increased to four units of 35 M.W. after 10 years. Thus the total installed capacity in the ultimate stage as envisaged will be 140 M.W.

Though the Scheme was included in the First Five-Year programme, the work could not be proceeded with for want of agreement between the two States. After personal contacts and discussions by the Minister in the States' capitals and at Delhi and by the good offices of the Centre, an agreement was reached, in November 1954, acceptable to both the parties concerned. We are now in a position to commence work on the project.

Prosperity to Madurai

The Periyar Hydro-electric Scheme will provide employment for a number of people of this area during the construction stage and with its completion, bring considerable prosperity not only to Madurai district but to the whole State. With cheap hydro-power available, it is expected that many industries, large and small, will spring up near the vicinity of the scheme area. Power will be available for extension to a number of villages for various purposes like irrigation and other agricultural operations as well as many small-scale and several major industries.

The railway line also may be extended, for the Scheme, to Gudalur and probably up to the Periyar Power Station in the near future. Thus, after the completion of the Vaigai Reservoir and the Periyar Hydro-electric Project, Madurai district will become one of the most enviable parts of the Madras State.

The present scheme provides for utilising a continuous discharge of 1,000 cusecs during irrigation season, i.e., from June to March and 300 cusecs from March to May during the period of irrigation closure. It is now possible to have this high discharge of 300 cusecs of water during non-irrigation season and store the same in the Vaigai Reservoir where it can be stored for irrigation purposes. It will incidentally help power development during non-irrigation periods. The cost of the Vaigai Reservoir is being suitably apportioned between the Public Works Department and the Electricity Department.

Improvements to the existing tunnel.—The capacity of the existing tunnel is only 1,300 cusecs, and this will be increased to 1,699 cusecs by increasing the area of cross-section of the tunnel from 96 to 154 square feet and lining it with concrete. The cost of this work will be shared suitably by the Electricity

Department and the Public Works Department, as by this improvement more discharge from the Periyar Lake into the Vaigai Reservoir is possible during irrigation period.

Tunnel pond and regulating reservoir.—Water from the above tunnel will discharge into a tunnel pond to be formed by a forebay dam which will be 93 feet high and will have a capacity of three million c.ft. Necessary surplussing arrangements and headworks for irrigation outlet and pressure tunnel for power-draft will be provided.

Pressure tunnel and surge shaft.—Water from the regulating reservoir will take off through a power tunnel to be drilled. This power tunnel will be of horse-shoe type and 4,188 feet long, the area of cross-section being 154 square feet. This tunnel will be capable of discharging a maximum of 1,600 cusecs.

The power tunnel will terminate into a surge tank of differential type which will be 180 feet high and 40 feet in diameter. It will be entirely in rock excavation and will be concrete-lined.

The fall in the tunnel will be such that the outlet end at the surge shaft would be well below the minimum draw-down level in the surge shaft to give an effective water seal.

Penstock.—Two numbers low pressure pipe-lines 10 feet in diameter will take off from the surge tank. After 194 feet, each low pressure pipe-line will branch off into two penstocks of 6 feet 6 inches diameter. Of these four high pressure pipes, one will be blank flanged for use at a later date and other three pipes will be connected to individual turbines. The pipe diameter in the three reaches are 78 inches, 72 inches, and 66 inches respectively before being connected to the turbine inlet valve.

The total length of the high pressure pipe is nearly 3,100 feet and each pipe is capable of discharging a maximum of 400 cusecs.

The penstock will roughly follow the line of shoulder which runs from the surge shaft to the Power-house. A haulage track along side the penstock will be constructed for conveying the construction equipment, etc., to the power-house.

Power-house and power plants.—The Periyar Power-house will be located in the Ghat Section of the main road from Cumbum to Thekkadi and will be about 35 miles from Theni, a town in Madurai district in Madras State.

A gross head of about 1,260 feet from the surge tank to the power-house site is available. The Scheme provides for the utilisation of a continuous discharge of 1,000 cusecs during irrigation season for about nine months in the year and a minimum of 300 cusecs during the irrigation closure period, i.e., the balance three months.

There will be initially three numbers 50,000 H.P. turbines each directly coupled to 35,000 K.W. 0·85 P.F. 3 phase 50 cycles 11 K.V. generator and the fourth set will be installed at a later date.

Out-door transformer yard.—The transformer yard will be located by the side of the power-house. The main structures will be

of the double deck type for carrying duplicate 110 K.V. busbars with necessary disconnecting switches.

Three numbers step-up transformers 11 KV/110 KV. 42,000 KVA capacity will be installed initially and one more similar unit will be added later. Besides there will be two numbers 3,000 KVA. 110 KV. 22 KV step-down transformers for the local supply.

Transmission system.—The power generated at Periyar Power-house will be fed into the existing power grid through 110 KV. transmission lines and will be in parallel with the following systems :—

1. Papanasam Electricity System at Madurai.
2. Pykara Electricity System at Sembatti.
3. Mettur Electricity System at Tiruchirappalli.

For this purpose the following transmission lines will be constructed initially :—

1. Periyar-Theni-Madurai 110 KV. double circuit line—80 miles.
2. Theni-Sembatti-Tiruchirappalli single circuit 110 KV line—108 miles.
3. Sembatti-Karur single circuit 66 KV line—53 miles.

In addition, the following lines will be constructed within a period of ten years from the time Periyar Power-house commences operation :—

1. Tanjore-Sivaganga 66 KV. single circuit line via Karaikudi, Pudukottai and Gandarvakottai—80 miles.
2. Sivaganga-Ramanathapuram 66 KV. single circuit line —50 miles.

Apart from the above trunk lines, the Scheme provides for nearly 150 miles of 33 KV. lines.

There will be about 80 miles of double circuit telephone lines and about 350 miles of single circuit telephone lines to facilitate communication between the other stations. Power-line carrier current communication will also be provided.

Sub-stations.—For distributing the Periyar power the existing sub-stations at Madurai, Tiruchirappalli, Karur, Sembatti and Sivaganga will be provided with adequate additional equipment and a new 110 KV. sub-station will be constructed at Theni and new 66 KV. sub-stations at Idayakottai, Aravankurchi, Pudukkottai, Gandarvakottai, Karaikudi and Ramanathapuram. There will also be a few new 33/11 KV. sub-stations for distribution purposes.

Camps and roads.—There will be two camps at Periyar, the upper camp being on the north of the ghat road near the 41st mile of the main road from Cumbum, and the lower camp being near the power-house site. Necessary roads and protected water-supply will be provided.

Estimated cost and financial results.—The estimated cost of the Scheme as submitted to the Planning Commission was Rs. 10·47 crores. The Scheme will be remunerative by more than just meeting the interest charges on capital outlay, depreciation charges, operation and maintenance charges and royalty to the Travancore-Cochin State.

Under the National Extension Service and Village Community Projects, the State Government have laid greater emphasis on the progress of rural electrification during the First and Second Five-Year Plans. As such, power demand is expected to increase considerably in course of time.

The Department has already started the preliminary works, and the civil works are in good progress. The scheme report contemplates a construction period of four years. Every endeavour is being made to bring the scheme to beneficial use in record time before 1958.

Load Breaking Capacity of Air Break Switches

By N. B. VASUDEVAN, B.E.,
Divisional Engineer (Electrical).

Rule 60 (1) (*d*) of the Indian Electricity Rules, 1937, stipulates that supply to every apparatus at medium or high pressure shall be efficiently controlled by suitable linked switches of requisite capacity to carry and *break* the current in each conductor placed near the apparatus. These switches should therefore be capable of not only carrying but also *breaking* the current. The object of the rule is obviously to enable cutting of supply to the equipment very quickly, in case of emergency, without having to switch off the load on the L.T. side, or to have to open out the fuse units or links, one by one.

The majority of distribution transformers in this State, both in the Government Electricity Department as also in the licensees' systems, are generally provided only with air break switches on the H.T. side. While oil circuit breakers are always designed to both carry and break the current supply to the equipment controlled, the question arises as to how far air break switches comply with the Indian Electricity Rule referred to above. The normal practice, where these switches are used, is for the load on the L.T. side of the transformer to be cut off before the A.B. switch is opened, which suggests that this switch may not comply with the Indian Electricity Rule.

When a high voltage circuit is broken, there is heavy arcing across the points of separation, which arc has a tendency to persist even after the circuit is opened. In the case of O.C.Bs. and Air Blast Circuit Breakers, the arc gets extinguished quickly by the oil or the blast of air blown across the gap of separation. But in the case of air break switches, there is no such provision to quench

the arc quickly. So the arc persists until the gap is wide enough, or the arc is blown to too long a length to persist. The provision of a set of opening out horns across the gap facilitates the arc getting extinguished, as it travels up in the diverging gap. But the arc can persist for a certain length, depending on the voltage and current broken, before it can be extinguished. Under adverse wind conditions this length of the arc and its deflection by the wind may be enough to cause a flash-over to the next phase or to earth. The horn gap air-break switches should therefore be designed with sufficiently ample clearances to prevent such flash overs, while opening on load.

The A.I.E.E. Transaction, Vol. 69, 1950, furnishes results of large-scale tests on air-break switches for testing suitable gap and phase to phase or phase to earth clearances necessary under actual operating conditions of voltage and current. The results arrived at after such tests lead to the following conclusions :—

(1) An open arc formed on adequately separated electrodes will go out, if it is free to expand to its critical length.

(2) A horn gap switch will successfully interrupt a current if its dimensions are adequate to permit the arc to grow to its critical length. An exception might be with the wind blowing *in line with* the arcing horns (not across), when the length is increased.

(3) With the conventional horn gap switches, arc length and reach are independent of the type of horn gap switch and of the speed of operation.

(4) Two arcs in series (centre rotating type) have about the same *total* length as a single arc produced under the same conditions though one of the pair may be longer than the other.

(5) Arcs are longer, when interrupting line charging currents than when interrupting a corresponding amount of resistive or inductive current with similar voltage across the gap.

(6) Reach for currents below 100 amps of resistive and inductive current depends on both voltage and current. Maximum reach for practical use in this range is 0·0165 foot per ampere per K.V. across open switch gap.

(7) On 132 K.V. horn gap switches having 16 feet separation horizontally between phases, about 7 amps of *charging current* can be opened with reasonable safety ; larger currents up to 20 amps can be broken if wind direction is favourable.

Of these conclusions the one under (6) is of great importance for the subject under discussion.

In this paper, the results of the safe reaches, on the basis of a number of experiments, have also been plotted in a graph. For reasonably safe operation, switches must have clearances greater than the safe reaches that may be normally expected as per these experiments. An upper limit above the highest test point would meet this requirement. A curve representing this upper limit of safe distances above the experimental reaches, is also

furnished in the same graph. From this it is seen that for an operating voltage of 11 K.V. (6·5 K.V. between phase and neutral) and about 25 amps current (500 K.V.A.) the phase to phase clearance in a horn gap switch should be about 6·5 × ·4 = 2·6 feet. From a formula which also is given in this paper, for safe distances, evolved as a result of these experiments, this clearance should be 0·0165 foot per K.V. per amp, i.e., 0·0165 × 6·5 × 25 = 2·68 feet. This is under the worst condition when the arc is almost drawn horizontally under low wind across the gap.

A separation of 2·5 to 3 feet between phases for 11 K.V. would therefore appear adequate for loads up to 500 K.V.A. With such separation, horn gap air-break switches may be deemed to comply with the Indian Electricity Rules. Above 500 K.V.A. it appears desirable to provide O.C.Bs. or oil immersed isolators.

Impedance Time Relays—Characteristics and Settings

By G. S. RAMA IYER, B.Sc., M.I.E.,
Executive Engineer (Electrical), &

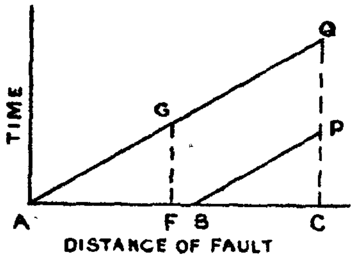
K. MADHAVANKUTTY MENON, B.Sc.,
Assistant Engineer (Electrical).

Scope

A scheme of protection using directional impedance time relays of sloping characteristics, has been commissioned on the 110 K.V. lines of the Madras Grid. The special features of protection, characteristics and settings of these relays are discussed in this article. Since this type of relay has been put in, in supersession of the FZA impedance/distance type relays of three steps characteristic, it is hoped that the information given herein may prove interesting and useful to the engineers of the operating systems.

General Principles

Impedance/time relay, as the name implies, operates in a time proportional to the impedance of the line from the relaying point to the fault. As the impedance of a line is proportional to length, the time-distance characteristics (with distance plotted in terms of impedance or length) is a sloping straight line as shown in Fig. 1.



TIME-DISTANCE CHARACTERISTICS

FIG. 1.

For a fault at any location such as F in Fig. 1, the operating time FG of relay at A is independent of the fault current but is determined by the impedance of the section AF. The time FG for a fault at any location F can be varied—in other words the sloping characteristic may be increased or decreased (as later discussed under time settings). But when once the time for a particular location of fault is fixed, the time for faults at all other locations is given by the straight line AGQ, i.e., if the time for a fault at a distance Z_0 is adjusted to have a value t_0 then the distance time characteristic is a straight line having a slope $\frac{t_0}{Z_0}$.

When two such relays are used for protection of successive sections, AB and BC, sufficient gradation is obtained by adjusting the slopes of the characteristics AGQ and BP.

In the case of parallel feeders or inter-connectors fed from both sides, a directional feature is also required. Consider the case illustrated in Fig. 2. It is obvious that unless directional feature as indicated is provided, the faulty section in any of the double circuit lines will not be isolated correctly. The principle in this regard is to set the relays for operation for power flow *away from busbars.*

Constructional Details

The relays used on the 110 KV. grid are of type NZA2 of Messrs. Metropolitan-Vickers Company make. The details furnished below relate to this type of relay.

The relay comprises of two elements, a directional element and an impedance/time element (vide details Figs. 3 and 4). The directional element operates on the watt-meter principle and consists of two electromagnets and a disc free to rotate between these electromagnets. The upper magnet is energised by the voltage obtained from the secondary of a potential transformer connected to the line and the lower magnet is energised from a current transformer. When power flow occurs in the desired direction, the contacts carried by the disc spindle close almost instantaneously.

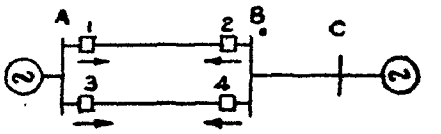


DIAGRAM OF DIRECTIONAL SETTINGS

FIG. 2

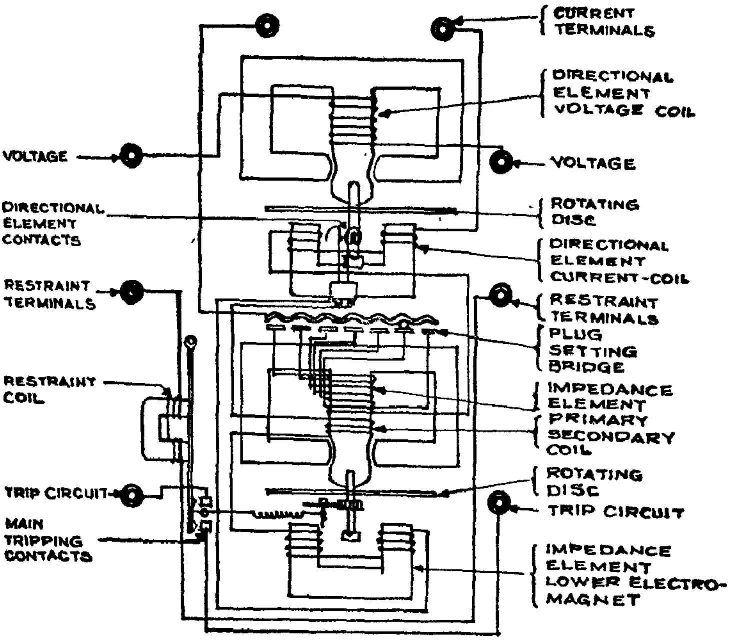


FIG. 3.

DIAGRAM OF INTERNAL CONNECTIONS OF THE TYPE NZA DIRECTIONAL IMPEDANCE/TIME RELAY.

The impedance/time element has two parts—a current operated induction element and a voltage operated restraint element. The current element is exactly similar to the element of an induction type O/L and E/L relays of the Messrs. Metropolitan-Vickers Company make and is connected to the secondary of the current transformer. This element will operate only when its secondary circuit is closed by the directional element contacts (vide Fig. 3). The primary winding is provided with taps as for usual O/L and E/L relays.

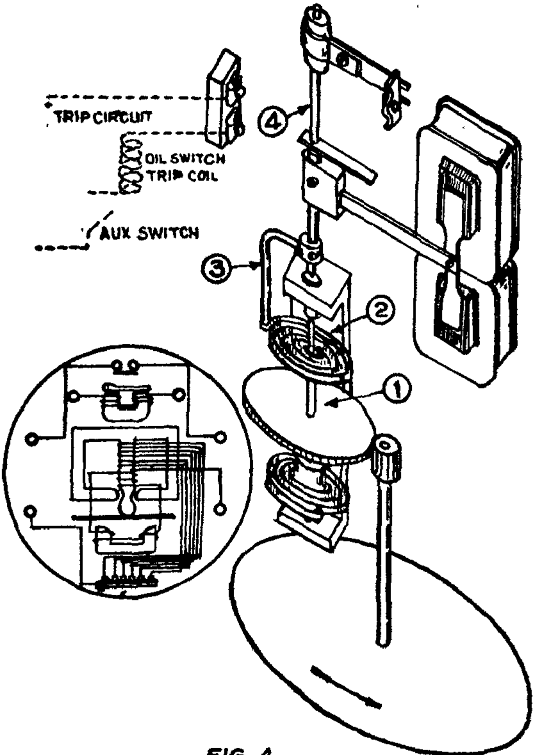


FIG. 4.

DIAGRAM TO ILLUSTRATE THE ACTION OF THE IMPEDANCE ELEMENT OF IMPEDANCE/ TIME RELAYS, TYPES PZA AND NZA.

The disc spindle of the current element is geared to a countershaft (1)—(Vide Fig. 4), which winds up a spiral spring (2). To the outer end of spiral spring is attached a bent lever (3) which turns another spindle (4) for sufficient torque to be developed; spindle (4) carries the contacts and a flat armature held against the face of the voltage restraint coil, which is energised from the secondary of a potential transformer.

Operation

On the occurrence of a fault, the current circuits of the impedance elements of the *appropriate* relays operate by the action of the directional element. A current proportional to the fault flowing in the current coil rotates the disc at a speed proportional to the current and

winds up the spring on the counter-shaft. When the torque exerted becomes greater than that due to the pull of the voltage restraint coil on the spindle carrying the armature, the armature is drawn away from the magnet and the contact closes the tripping circuit. From the above it is clear that the time of operation of the relay can be expressed as $t = k. \frac{v}{i}$ where

v = voltage in the relay
i = current in the relay
k = constant.

The ratio $\frac{v}{i}$ is porportional to the impedance of the line from the relaying point to the fault, as v & i are proportional to the line voltage V and line current I and $V = I Z$ where Z = line impedance from the relaying point to point of fault (voltage at any point being merely the impedance drop in the line). Hence the relation $t = KZ$ is obtained.

Characteristics

From a consideration of the principle of operation, it will be seen that the relay operation has the following characteristics :—

(1) The operation of the relay does not depend on the existence of a definite magnitude of current or voltage; the relay will operate in a time proportional to the ratio of the voltage and current applied.

(2) For a fault at any one particular location, the ratio of $\frac{v}{i}$ (whatever may be the magnitude of the fault current) remains constant and time of operation therefore also remains constant.

(3) The time/distance characteristic is a straight line with a slope $\frac{t_0}{z_0}$ where t_0 is the time (constant in magnitude) for the fixed location of the fault at distance Z_0 (measured in ohms or length).

The above characteristics, however, are not achieved in actual practice and the following deviations should be noted :—

(1) The curve does not start at zero time for zero distance. A min. time of 0·25 sec. is required for operation even when voltage is zero. Hence the straight line characteristic starts from time t = 0·25 sec. for zero distance and has the slope $\frac{t_0 - 0{\cdot}25}{Z_0}$

(2) The constancy of time for a particular ratio of $\frac{v}{i}$ (i.e., faults at the same location with different fault current) is not obtained. The variations in this regard can be studied for the curves given in Fig. 5. While the time should be the same for constant value of $\frac{v}{i}$ it is seen in actual characteristics, that the time is slightly different for different values of v and i, even though the ratio of $\frac{v}{i}$ is constant. It is the usual practice to specify the time for all settings corresponding to four times the setting value of current and the voltage corresponding to this 4 times current setting and the setting impedance. The assumption therefore that for a particular fault location, the time is constant, is not quite correct. Though the ratio $\frac{v}{i}$ remains constant, the times obtained for different magnitudes of fault currents are different. The value obtaining at four times the setting value is normally taken for guidance.

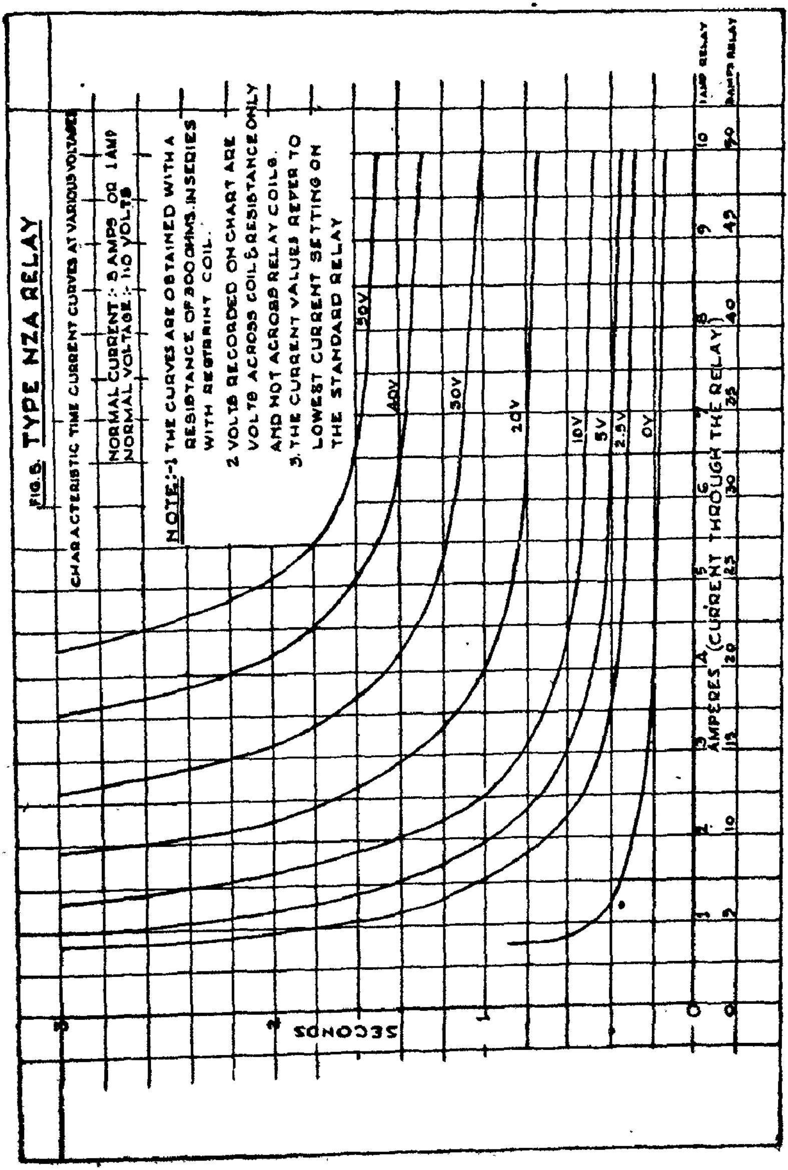


FIG. 5. TYPE NZA RELAY
CHARACTERISTIC TIME CURRENT CURVES AT VARIOUS VOLTAGES
NORMAL CURRENT :- 5 AMPS OR 1 AMP
NORMAL VOLTAGE :- 110 VOLTS
NOTE:- 1 THE CURVES ARE OBTAINED WITH A RESISTANCE OF 300 OHMS. IN SERIES WITH RESTRAINT COIL.
2 VOLTS RECORDED ON CHART ARE VOLTS ACROSS COIL & RESISTANCE ONLY AND NOT ACROSS RELAY COILS.
3. THE CURRENT VALUES REFER TO LOWEST CURRENT SETTING ON THE STANDARD RELAY
50V
40V
30V
20V
10V
5V
2.5V
0V
SECONDS
3
2
1
AMPERES (CURRENT THROUGH THE RELAY)
0 1 2 3 4 5 6 7 8 9 10 1 AMP RELAY
0 5 10 15 20 25 30 35 40 45 50 5 AMPS RELAY

Settings

There are two settings for the relay—

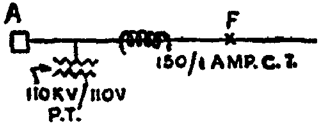
(1) Current setting or tap setting.

(2) Time setting or resistance setting.

Tap setting.—The tap settings are obviously intended to prevent operation of the relay due to load current. It is conceivable that under normal conditions the relay may operate under the influence of the normal voltage and the load current. As explained already, the magnitude of the voltage and current need not reach any particular values for the relay operation, as what counts is merely the ratio of the voltage to current. Hence even under normal conditions of load, the relay may operate in a time which can be evaluated from curves in Fig. 5. By choosing proper taps for the current coil the relay can be made to operate only when the current exceeds the load current. This explains why curves in Fig. 5 are asymptotic near current zero. Where the short circuit current is not much in excess of the load current, this method is not feasible and special auxiliary relays are required. In such cases, the tap is set at minimum value.

The tap setting has also a bearing on the choice of resistance, as discussed under time setting.

Time setting.—Referring to Fig. 1, the relays have to be set to have a definite time of operation for a fault at any known location. This setting is done by inserting a resistance 'R' in the voltage coil of the relay so that the effective voltage on the relay coil is altered.



CIRCUIT FOR EXPLAINING EFFECT OF RESISTANCE IN VOLTAGE COIL ON TIME.

FIG. 6.

The effect of resistance in the voltage coil circuit, on the time of operation, can be illustrated by the following example :—

Line volts (normal)—110 KV.
P.T. ratio—110 KV/110 V.
C.T. ratio—150/1.
Relay—1 amp—100%.
Tap setting—80%.

Consider a fault at F with impedance of section AF = 15·5 ohms per phase.

For a phase to phase fault loop impedance = 31 ohms, i.e., twice 15·5 ohms.

Fault current corresponding to 4 times setting = 4 × 120 or 480 amps.

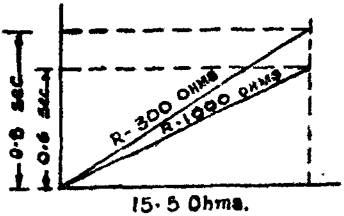
Line voltage at A under fault—
$4 \times 0{\cdot}8 \times 150 \times 2 \times 15{\cdot}5 = 14{,}880.$

Secondary voltage—$v = 14{\cdot}88$ volts.

Secondary current—$i = 3{\cdot}2$ amps. From curves in Fig. 5, the time of operation is 0·8 sec. and the time-distance curve will be as shown in Fig. 7. It may be noted that the curves in Fig. 5 are plotted with 300 ohms. 'resistance' in the voltage coil circuit. If now a resistance of 1,000 ohms is connected in the voltage coil circuit of the impedance/time element, instead of 300 ohms, the time of operation for a fault at F and with the same fault current of

480 amps. is 0·6 sec. as explained below:

The curves in Fig. 5 are with 300 ohms. resistance in series with the voltage coil and the voltages are measured across the resistance and voltage coil. Let the impedance of the coil (resistance only considered) be 400 ohms. Then with 1,000 ohms series resistance, instead of 300 ohms the equivalent voltage across a 300 ohms resistance and the voltage coil of 400 ohms to be used in curve will be $\frac{14{\cdot}88 \times (400 + 300)}{400 + 1{,}000} = \frac{14{\cdot}88 \times 700}{1{,}400}$, i.e., 7·44 volts and the time for this secondary voltage and 3·2 amps secondary current is 0·6 sec. The time-distance curve with 1,000 ohms instead of 300 ohms is also shown in Fig. 7.



TIME DISTANCE CURVES WITH DIFFERENT RESISTANCES IN VOLTAGE COIL CIRCUIT.

FIG. 7.

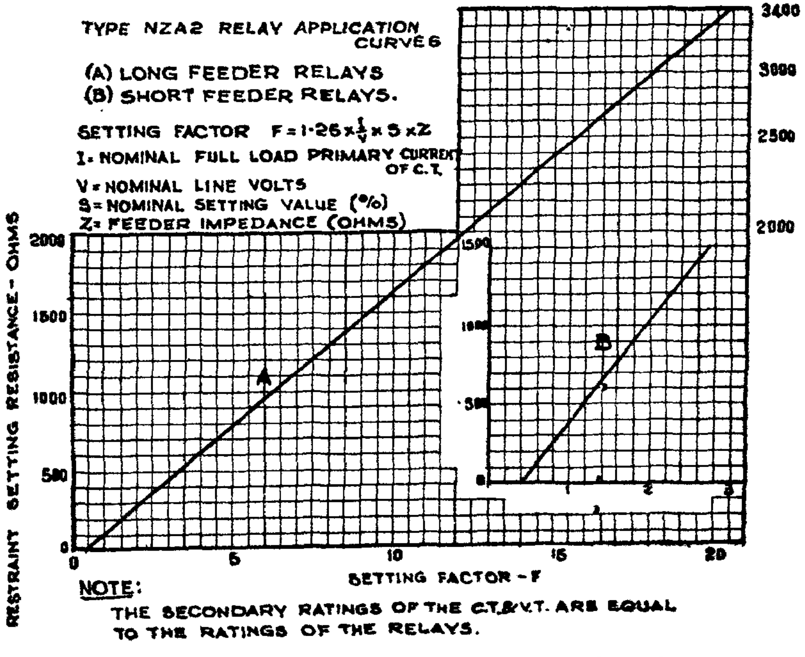


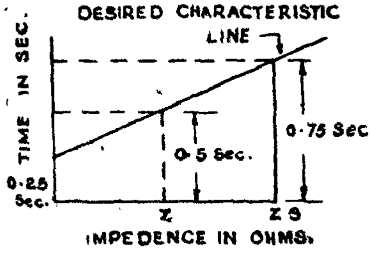
FIG. 8. TYPE NZA 2. RELAY APPLICATION CURVES

The resistance to be introduced for obtaining a definite time for a definite impedance (i.e. particular fault location) can be calculated by the above method but an easier method is to use what is known as resistance curves. These curves give the values of resistance required to give a definite time of operation (0·75 sec.) for given values of line impedance, P.T. ratio, C.T. ratio and tap setting. A typical curve is given in Fig. 8. It can be shown mathematically that the resistance curve is a straight line.

If the time is to be adjusted to any desired value say 0·5 sec. for a fault on any section having an impedance value Z_0, then the value of impedance to be adopted in calculating the setting factor is called 'setting' impedance (Z_s) and can be calculated from the relation

$$Z_s = Z_s \left[\frac{0{\cdot}75 - 0{\cdot}25}{0{\cdot}5 - 0{\cdot}25}\right] = Z_0 \times \frac{0{\cdot}5}{0{\cdot}25}$$

This can also be obtained graphically as illustrated in Fig. 9. Z_s being the abscessa for an ordinate of 0·75 sec. on the desired characteristic line.



RELATION BETWEEN SETTING IMPEDENCE AND SECTION IMPEDENCE

FIG. 9

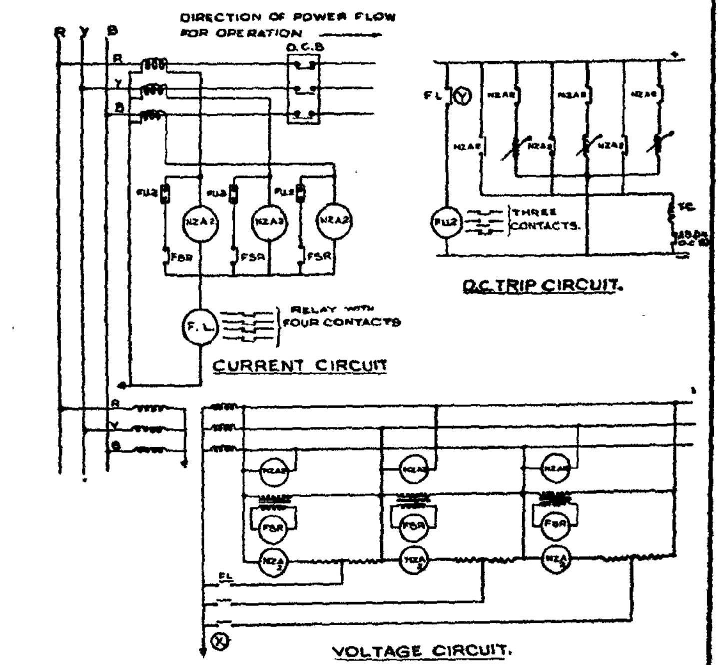
The need for the use of the evaluated value Z_s in place of Z_0 in calculating the setting factor, is obvious from the fact that the resistance curves give the values of resistance to give an operating time of 0·75 second for the impedance adopted in the calculation of the setting factor.

Auxiliary Relays

(1) *Earth fault and phase fault selection.*—For the proper functioning of the relay, it is necessary that the voltage and current applied to the relay have a ratio corresponding to the impedance of the faulty section. For this condition to be fulfilled, phase-to-neutral voltage should be applied to the relay for earth faults and phase-to-phase voltage for phase faults. Further the ratio of voltage to current will not remain the same for earth fault and phase fault at the same location, as the impedance of the fault loops are different. In order to obtain the same time of operation for a fault at the same location whether the fault is an earth fault or phase fault different resistances have to be introduced according to the nature of fault, in view of the differences in the impedances under the two types of fault for the same fault location. The change in connection in the voltage and resistance is brought about by auxiliary relays.

(2) *Starting relays.*—As already explained under tap setting, starting relays are required to prevent operation under load, where short circuit current is not in excess of load, and tap setting is not feasible.

The connections of the auxiliary relays is given in Fig. 10 for a typical scheme.



REFERENCE :-

—○— OPERATING COIL OF POWER TYPE RELAY

—⊣⊢— NORMALLY OPEN CONTACT OF POWER TYPE RELAY

—⊡— " CLOSED " " " "

—∿∿∿— RESISTOR

NOTE :-

1. THE F.L. RELAY CHOOSES THE APPROPRIATE RESTRAINT RESISTANCE FOR EARTH FAULTS BY CLOSING CONTACTS AT Ⓧ

2. FOR AN EARTH FAULT THE F.U 2 RELAY OPERATS THROUGH THE CONTACT Ⓨ OF F.L RELAY IN THE RESIDUAL CIRCUIT AND OPENS THE F.U 2 CONTACTS THERBY ENERGISING N Z A 2. RELAY COIL

3. FOR A PHASE FAULT THE F.S.R. UNDER VOLTAGE RELAY, CONNECTED ACROSS THE PHASES ON WHICH FAULT HAS OCCURED, GETS DE-ENERGISED AND F.S.R CONTACTS OPEN ENERGISING THE NZA 2 RELAY COIL

FIG. 10. SCHEMATIC DIAGRAM OF CONNECTIONS NZA 2. IMPEDANCE / TIME PROTECTION FOR EARTH AND PHASE FAULTS

COMPARED.

Parallel Feeder Characteristics.

The conclusion that the time/distance characteristic is a straight line with a slope $\frac{t_1}{Z_1}$ (neglecting 0·25 sec. time for zero impedance) is justified only if the ratio of line voltage and line current at every point is equal to the impedance of the fault section. In case of parallel feeders, where the distance is plotted in terms of impedance of a single circuit, the relation does not always hold good and hence the characteristics require slight modification. Consider the circuit given in Fig. 11.

Let the impedance of each feeder in section AB be Z_1 and that in section BC be Z_2. Distance will be plotted in terms of single circuit impedance. Assume the relays at A are set for a time t_1 for a fault for the impedance Z_1 of a single feeder in section AB. The characteristics of relays at A may be examined under different conditions. Let the current on each feeder at A be denoted by I and voltage by V. Let distance be measured in terms of single circuit impedance and denoted by Z.

Condition I—Single circuit in section AB and single circuit in section BC.—The characteristic will be a straight line having a slope $\frac{t_1}{Z_1}$ as indicated by APQ 2 in Fig. 12, since the relation $V = IZ$ holds good for faults anywhere between A & C.

Condition II—Double circuit in section AB and single circuit in section BC.—Fault between A & B.—The relation $V = IZ$ still holds good and hence characteristics coincide with AP in Fig. 12.

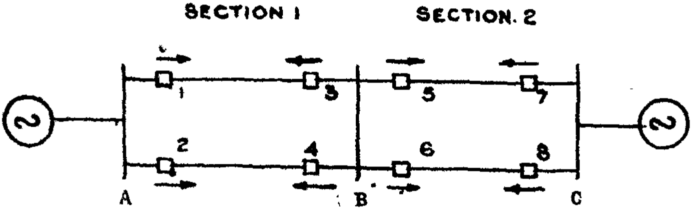
Fault between B & C.—The relation between V and I is:

$V = IZ_1 + 2I\,(Z\text{-}Z1)$, current in the single feeder BC being

$2I = 21Z - IZ_1$; $\frac{V}{I} = 2Z - Z_1$

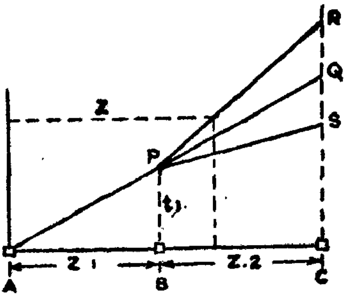
If $\frac{V}{I}$ were equal to Z the characteristic will be PQ. A little consideration will show that the time may be expressed as $t = \frac{V}{I} \times \frac{t_1}{Z_1}$.

The time distance curve is a straight line with slope $2 \times \frac{t_1}{Z_1}$, i.e.,



PARALLEL FEEDERS

FIG. 11.



TIME DISTANCE CURVES FOR DIFFERENT CONDITIONS.

FIG. 12.

double slope of AP and passes through point P (t_1, Z_1).

This is shown by PR in Fig. 12.

Condition III—Single circuit in section AB and double circuit in section BC.—By similar reasoning as in case II, it can be shown that the characteristics will be AP for fault between A & B and a line with half slope of AP passing through P, for faults between B & C—This is shown by AP—PS in Fig. 12.

Condition IV—Double circuit in section AB and double circuit in section BC.—The characteristics will be as in case 1., i.e., st. line APQ with slope t_1/Z_1 will be the time/distance characteristic for faults between A & C.

Denoting the slope t_1/Z_1 as normal, the following will be the characteristics for the conditions considered :—

(1) The slope of the characteristic will be normal for faults in the first zone for all conditions, i.e., the characteristic AP holds good for the first zone faults, in all cases.

(2) The characteristic will have normal slope, double normal slope and half normal slope for faults in the succeeding zone for the following conditions :—

(*a*) Conditions I & IV—Normal slope.

(*b*) Condition II—Double slope.

(*c*) Condition III—Half slope.

NOTE.—For faults in zone (1) the relay of the concerned feeder alone will act, for faults in zone (2) relays on both feeders will act simultaneously.

Conclusion

Study is being made of the actual performance of the Impedence Time Relays installed on the 110 K.V. grid lines. It is proposed to give a review of actual commissioning tests and the subsequent performance of the relays up to now in a succeeding article.

20 DEC 1955

Carrier Current Communication in the Madras Grid

By S. KRISHNASWAMI, B.Sc., C.I.I.Sc.,
Executive Engineer (Electrical).

Introduction.—The Telephone communication in the Department is at present by means of separate telephone lines run parallel to or under the power lines using manually operated local battery or magneto type telephones with code ringing. This system which is intended for short distance communication, suffers from several disadvantages like noise, poor audibility with distance, atmospheric disturbances, line failure under storm, theft of conductors, etc., and is no longer suitable for the satisfactory operation of the Power Grid, with a vast programme for its expansion.

The latest modes of communication adopted by power utilities are carrier current communication and high frequency radio links. Since the use of H.F. radio links has been restricted in India by the P. & T. Department for the use of aviation, navigation, military, police and railway only, the Department has to go in for carrier current communication between power stations and important sub-stations.

In the first instance, carrier sets will be installed at Basin Bridge, Korattur, Singarappet, Mettur, Erode, Moyar, Pykara, Thudiyalur, Udumalpet, Madurai, Papanasam and Tiruchirappalli, and they are expected to go into service before March 1956. This will be further extended to Periyar, Theni, Sembatti and Tiruchirappalli, as soon as the 110 KV power lines under the Periyar Scheme are completed.

The present article covers briefly the fundamental principles of carrier communication over power lines. The second one to follow will deal with salient features of the carrier current equipment ordered for the Madras Grid.

2. *Power line carrier.*—The power line carrier utilizes the existing E.H.T. power lines for the transmission of speech and signals, thus dispensing with the need for separate telephone lines. This transmission consists of super-imposition on the power line of a high frequency current which can be easily separated out at the receiving end from the power frequency by means of filters. As shown in Fig. 1 the coupling to the power line is done by coupling condenser which in conjunction with the filter device allows the high frequency currents to pass, while preventing the power frequency currents from entering the signal equipment. The carrier frequency equipment consists of high frequency transmitter and receiver. At the transmitting end, the carrier frequency gets modulated by the voice frequency. At the receiving end the modulated carrier is demodulated to the voice frequency and is

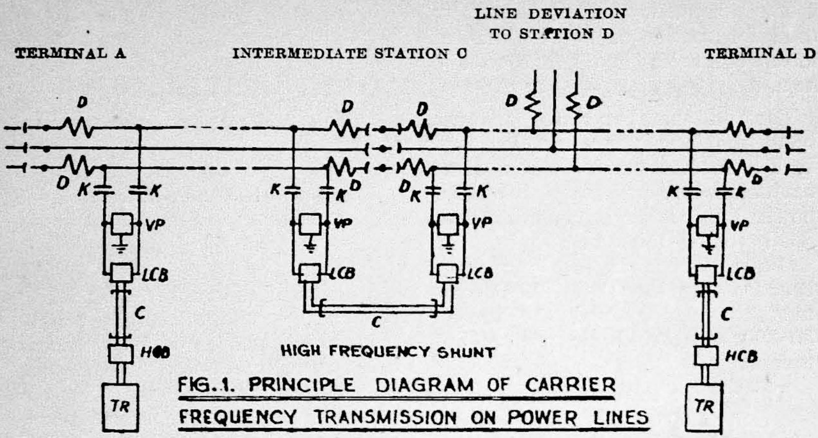


FIG. 1. PRINCIPLE DIAGRAM OF CARRIER FREQUENCY TRANSMISSION ON POWER LINES

TR. CARRIER FREQUENCY EQUIPMENT
H.C.B. MATCHING TRANSFORMER
C. HIGH FREQUENCY CABLE
L.C.B. LINE CONNECTING FILTER
V.P. VOLTAGE PROTECTING DEVICE
K. COUPLING CONDENSER
D. HIGH FREQUENCY CHOKE COIL

separated out and connected to the telephone receiver. In a similar manner other signals for calling, relaying, telemetering, load frequency controlling and supervisory controlling can be transmitted.

3. *Frequency range.*—The frequency range normally used for carrier on power lines, in relation to those used for other purposes is indicated in Fig. 2.

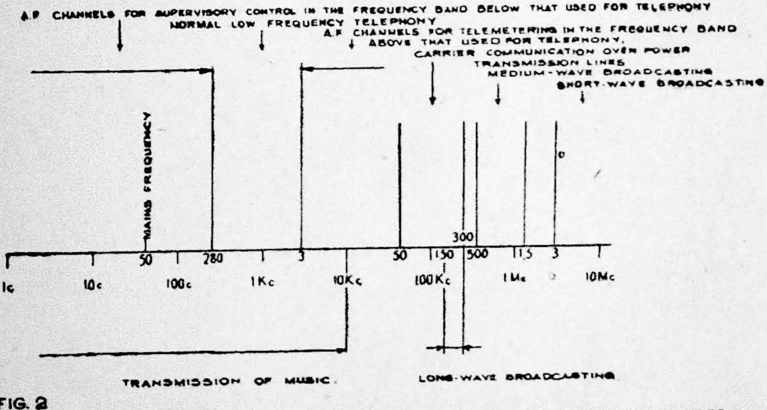


FIG. 2

FREQUENCIES USED FOR CARRIER COMMUNICATION OVER POWER TRANSMISSION LINES IN RELATION TO THOSE USED FOR OTHER COMMERCIAL PURPOSES.

The frequency band normally used for carrier on power lines in most countries is 50 kc/s to 300 kc/s.

Part of this band overlaps the band for long wave broadcasting. It is for this reason that in some countries the frequency band for power line carrier is generally confined to 50–150 kc/s only. In India as there is no long wave broadcasting the P. & T. Department have permitted the use of 50–300 kc/s band for power line carrier.

Though for transmission of music the frequency range of 30 to 10,000 c/s is adopted in radio, the range of 300–2,400 c/s is considered adequate for understandable transmission of speech over the carrier. Frequencies outside this range contribute only slightly to the intelligibility, as discussed in the next paragraph.

The frequencies allocated for transmission of speech and pulses for other purposes are as follows :—

	Purpose.	*Frequency in cycles per second.*
1	Calling channel	100
2	Remote control and supervisory channel.	240.
3	Speech channel.	300 to 2,400
4	Relaying channel.	2,460
5	Remote control and supervisory channel.	2,580
6	First Telemetering channel.	2,770 to 3,230
7	Second Telemetering channel.	3,450 to 3,950

In each of the above telemetering channels, 4 sets of values can be transmitted as the frequency separation generally adopted between two telemetered values is 120 c/s. However in case separate transmitter of 2·5 kc. bandwidth is used for telemetering alone, it is possible to transmit 18 values.

4. *Speech and sound waves.*—Speech is made up of complex waves, each with a wave of fundamental frequency, over which is superposed waves whose frequencies are whole multiples of the fundamental frequency. Fig. 3 shows how a complex wave results from combination of Sinusoidal waves. It is the fundamental or the "Pure-tone" which gives the complex tone its characteristic pitch. The harmonics or overtones determine the tonal quality of the note. It is therefore, important that if naturalness is required in any sound transmission system, the higher frequency harmonics must be faithfully reproduced. Normally for good (but not perfect) reproduction the general tonal quality of any note will be distinguishable if only the overtones up to at least twice the frequency of the fundamental, i.e., second harmonics are uniformly reproduced.

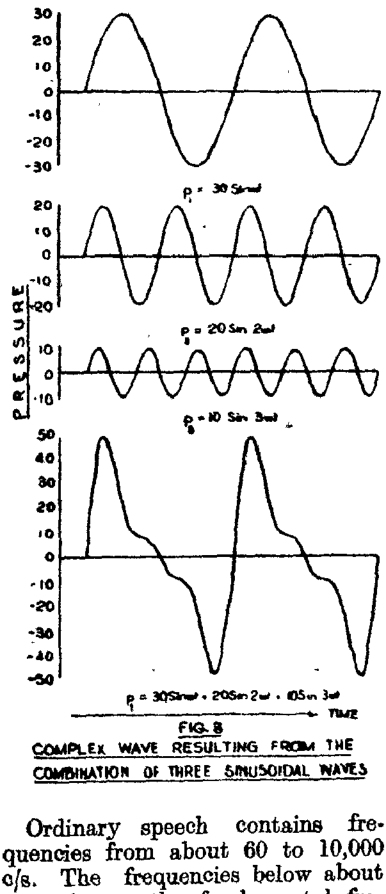


FIG. 8
COMPLEX WAVE RESULTING FROM THE COMBINATION OF THREE SINUSOIDAL WAVES

Ordinary speech contains frequencies from about 60 to 10,000 c/s. The frequencies below about 300 c/s are the fundamental frequencies and are responsible for the greater part of the energy of the speech, but it is the higher frequency components which although containing very little energy determine to a large extent the intelligibility of speech. The fundanental frequency of the normal speaking voice is approximately 75 c/s for males and 300 c/s for females. It is impossible in any telephone system to transmit the whole range of frequencies, since the cost of a transmission system increases rapidly as the frequency range is widened. It is therefore necessary to decide the minimum frequency range necessary to give the required degree of understandability. The understandability falls only slightly when frequencies above 2,500 c/s and below 500 c/s are cut off. But if frequencies below 2,500 c/s are cut off the understandability falls very rapidly until at about 500 c/s it is not much more than 5 per cent. But it is frequencies below 500 c/s which have a substantial effect on the naturalness of reproduced speech. In a telephone system however understandability is the main aim and naturalness of voice is only of secondary importance. The internationally agreed frequency range for telephony is therefore, 300 c/s to 2,500 c/s. In this connection, it would also be interesting to mention that though the frequency range over which the average human ear will respond is in the order of 30 to 20,000 c/s the maximum sensitivity occurs at about 2,000 c/s and the ear has the maximum range of volume response within the frequency band of 500 c/s to 2,500 c/s necessary for good understandability of the speech.

5. *Function of the carrier.*—In ordinary telephony, the sound wave is converted into audio-frequency electrical oscillations by the microphone and is superimposed on the D.C. current of the battery which acts as the carrier. On a pair of wires, only one telephone conversation can take place at a

time. Because of the higher resistance of the telephone lines, the attenuation is great. The interefrence on telephone lines due to induction on account of power system faults and harmonics is also great. In view of these factors the range and speaking facilities of the oridnary system of telephone communication systems are limited.

In the carrier system of communication, the audio-frequency waves are shifted from their normal position in the frequency spectrum to any desired higher position in the frequency spectrum at which the speech energy may be satisfactorily transmitted over long distances. At the receiving end, they are again brought down to their normal position in the frequency spectrum. By choosing different carrier frequencies any number of speech transmission channels could be created over the same pair of wires. As the transmitted wave is of very high frequency, interference on account of

(*a*) power system harmonics, and

(*b*) induction due to power system faults,

is eliminated. Consequently the transmission range and speaking facility with carrier system are greater than with the ordinary telephone system. The carrier communication system can be had both on telephone lines and power lines. In the latter case it is more reliable because of the greater mechanical strength of the power line.

6. *Modulation.*—The shifting of audio-frequency waves from their normal position in the frequency spectrum to a higher position in the spectrum mentioned above is called Modulation and is done as follows: A valve or crystal oscillator generates a continuous wave oscillation of high frequency. The audio-frequency electrical oscillations produced by the microphone circuit are superimposed on the continuous wave high frequency oscillation called the carrier wave. The resultant waveform is known as a modulated wave. The modulated carrier wave exhibits no physical audio-frequency properties. At the receiving end, the carrier is eliminated by the detector and only the audio-frequency oscillations of the modulating signal are applied to the telephone receiver.

The carrier, as generated, is a simple form of alternating current and is practically a sine wave. As such it has three dimensions, viz., amplitude, frequency and phase which can be varied, resulting in

(*a*) amplitude modulation,

(*b*) frequency modulation, and

(*c*) phase modulation.

(*a*) *Amplitude modulation.*—In this the amplitude of the carrier wave is made to vary following similar variations in audio-frequency currents. The frequency and phase of the carrier wave remain unaffected. This is illustrated in Fig. 4. 'A' shows the unmodulated carrier wave. In B the carrier wave is assumed to be modulated by a signal having the wave shape shown. Thus if X is the amplitude of the unmodulated carrier wave and Y the amplitude of the modulating signal, the variation of the resultant

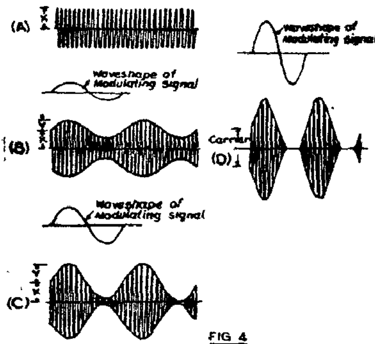


FIG 4

GRAPHICAL REPRESENTATION OF (A) CARRIER UNMODULATED, (B) MODULATED 50% (C) MODULATED 100% (D) AN OVER MODULATED R.F CARRIER WAVE

carrier amplitude takes place between the limits X plus Y and X minus Y. The diagram C shows what happens with a stronger modulating signal. In this case the strength of the modulation is such that when the modulating signal reaches its positive peak, the carrier amplitude is doubled and when it reaches its negative peak, the carrier amplitude is zero.

When a modulated carrier wave is detected at the receiver, the sound that comes out of the telephone is caused purely by the modulating signal and not by the carrier. Therefore, the greater will be the useful receiver output, the stronger the modulating signal. The wave modulated as shown in Fig. 4-C would produce considerably more useful signal than the one shown at B. The depth of modulation is represented as a percentage of the carrier amplitude. If X is the carrier amplitude and Y the amplitude of the modulating signal, then the percentage modulation is $y/x \times 100$. When the amplitude of the modulating signal is equal to that of the carrier, the modulation is 100 per cent.

If the carrier is modulated more than 100 per cent the result will be a condition as shown in Fig. 4-D. Not only does the peak amplitude, exceed twice the carrier amplitude, but also, there exists a period during which the output is cut off entirely. Communication will therefore be interrupted during this period. It is therefore of utmost importance that overmodulation of more than 100 per cent is avoided. Generally in carrier systems, the percentage modulation is of the order of 80 per cent.

The amplitude values shown in Fig. 4-C may represent either the current or the voltage (instantaneous values). Power varies as the square of either the current or the voltage. So at the positive peak of modulation the instantaneous power in the modulated wave is four times the unmodulated carrier power. But the average power in a 100 per cent modulated wave is 1½ times the power in the unmodulated carrier. This in effect means that the power output of the transmitter increases by 50 per cent with 100 per cent modulation.

This will be the case if the modulating signal is a pure sine wave. But the wave form of speech is a complex one and does not contain as much power as there is in a pure sine wave. On an average, speech waveforms will contain only about half as much power as a sine wave, both having the same peak amplitude. The average power output of

the transmitter therefore increases only by about 25 per cent instead of 50 per cent with 100 per cent modulation. But as the instantaneous power increased by 4 times, the peak power output capacity of the transmitter must be the same for any type of modulating signal. This is discussed in further detail while considering the different systems of transmission.

(*b*) *Frequency modulation.*—In this system of modulation, the frequency of the carrier wave is made to vary above and below the modulated carrier frequency the variations being made to follow closely the audio-frequency currents. This is illustrated in Fig. 5. The diagram A represents the carrier wave, the diagram B the modulating signal and C the resultant frequency modulated wave.

It may be seen from the figure that when a modulating signal is applied, the carrier frequency is increased during one half cycle and decreased during the other half cycle of the opposite polarity. The carrier frequency cycles occupy less time (higher frequency) when the modulating signal is positive and more time (lower frequency) when the modulating signal is negative. The change in carrier frequency (frequency deviation) is proportional to the instantaneous amplitude of the modulating signal; hence the deviation is small when the instantaneous amplitude of the modulating signal is small and is great when the modulating signal reaches its peak either positive or negative. In frequency modulation the power output of the transmitter does not change, since there is no change in amplitude.

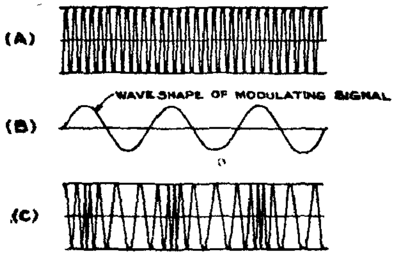


FIG. 5.

GRAPHICAL REPRESENTATION OF FREQUENCY MODULATION. IN THE UNMODULATED CARRIER AT A, EACH R.F. CYCLE OCCUPIES THE SAME AMOUNT OF TIME WHEN THE MODULATING SIGNAL, B, IS APPLIED. THE RADIO FREQUENCY IS INCREASED AND DECREASED ACCORDING TO THE AMPLITUDE AND POLARITY OF THE MODULATING SIGNAL

(*c*) *Phase modulation.*—In this system the phase of the carrier is advanced and retarded by the modulating audio-frequency current. The frequency of an alternating current is determined by the rate at which its phase changes. If the phase moves through 360° in one second the frequency is one cycle per second but if the phase moves through 1080 degrees (3 × 360) there are three complete cycles in one second. If the phase of the current in a circuit is changed, there is an instantaneous frequency change during the time the phase is being shifted. The amount of frequency change or deviation depends on how rapidly the phase shift is accomplished. It is also dependant on the total amount of phase shift. The amount of phase shift is proportional to the instantaneous amplitude of the modulating signal. The rapidity of the phase shift is directly proportional to the frequency of the modulating signal.

Hence in phase modulation, the frequency deviation is proportional to both the amplitude and frequency of the modulating signal. This is the main difference between frequency modulation and phase modulation, since in frequency modulation the frequency deviation is proportional only to the amplitude of the modulating signal.

7. *Side-bands.*—The modulated carrier wave can be considered as the resultant of a number of superimposed high frequency oscillations which differ both in amplitude and frequency from one another but each of which is of constant amplitude and frequency (i.e.) possesses a continuous wave form. For example the sinusoidally modulated carrier wave shown in Fig. 4-C can be considered as the resultant of three continuous H.F. oscillations, whose frequencies are the frequency of the carrier wave and the frequency of the carrier plus and minus the modulating frequency respectively. If the frequency of the carrier is X and the superimposed audio-frequency is Y, the frequencies of the three continuous wave oscillations (whose resultant is the modulated carrier wave) are X; X + Y and X—Y. The latter two are called sidebands, X+Y being the upper sideband and X—Y the lower sideband.

Mathematically this can be represented as follows :—

Let the carrier of frequency $\frac{w}{2\pi}$ and amplitude A be represented as A Sin wt. Let the superimposed audio-frequency wave be B Sin Pt where the frequency is $\frac{P}{2\pi}$ and amplitude is B. The amplitude of the modulated carrier will be (A+B Sin Pt.) and the expression of the wave will be

$$(A + B \sin Pt) \times \sin wt.$$

$$= A \sin wt + \frac{B}{2} \cos (w - P)t - \frac{B}{2} \cos (w + P)t$$

$$= A \sin wt + \frac{B}{2} \sin \left[(w - P)t + \frac{\pi}{2} \right] + \frac{B}{2} \sin \left[(w + P)t - \frac{\pi}{2} \right]$$

These represent the unmodulated carrier, the lower side-band and upper sideband oscillation whose amplitude is half the depth of modulation.

As already stated, speech consists of complex vibrations which can be resolved into a number of pure tones (i.e., sinusoidal audio-frequency oscillations). Hence when a carrier wave is modulated by the audio frequency oscillations corresponding to the complex vibrations, the modulation of the carrier by each pure tone is equivalent to the production of three continuous wave radio-frequency oscillations. The wave transmitted may therefore, be analysed into a continuous wave oscillation at the carrier frequency and a large number of continuous wave oscillations whose frequencies are greater and less than that of the carrier by amounts equal to the frequencies of the original component pure tones in

speech. If the carrier frequency is 100 Kc/s and the limiting frequencies of speech are 300 to 2,500 cycles/sec., the upper sideband is from 100,300 to 102,500 cycles/sec. and the lower side-band is from 99,700 to 97,500 cycles/sec. The modulated wave thus covers a considerable band of frequencies the width of the band being twice the highest frequency of the modulating signal ($2 \times 2{,}500 = 5{,}000$ cycles/sec.). A receiving circuit for such waves must therefore, be adjusted so that all frequencies in the band are equally well received and to prevent interference in reception the difference between the carrier frequencies of any two R/T transmitters must be more than the sum of their highest modulation frequencies.

8. *Transmission.*—The audio-frequency sounds are entirely contained in the side-bands and the audio-frequency modulation is the beat or difference in frequency between any side-band and the carrier. It is this beat frequency between the carrier and its side-bands which appears at the receiving end after detection. In order to produce the requisite beat frequencies after detection we only need to have the carrier wave and one of its side-bands. Or even the carrier need not be transmitted since it could be supplied at the receiving end by means of a local oscillator. The common methods of transmitting intelligence or speech by modulating a carrier wave are therefore—

(1) Transmission and reception of the carrier with both side-bands.

(2) Transmission and reception of the carrier with one side-band only.

(3) Transmission of one side-band only, carrier being replaced at the receiver.

(4) Transmission of both side-bands only, carrier being replaced at the receiver.

This is illustrated in Figure 6.

9. *Comparison of the different types of modulation.*—The important difference between amplitude modulation and frequency modulation is that in A.M. the amplitude of the resultant modulated wave varies from that of the modulated carrier, whereas in F.M. the amplitude of the resultant modulated wave is the same as that of the unmodulated carrier. From this essential difference, follow the merits of the two systems.

(1) Since the power is directly proportional to the amplitude, in a amplitude modulated system, the average power output increases by 50 per cent during modulation (if the modulation is 100 per cent). In frequency modulation as the amplitude is constant, the transmitter power output does not change.

(2) Noise is fundamentally an amplitude effect. In an amplitude modulated system, the detector at the receiving end responds to noise as readily as it does to the signal. However, if the receiving system responds primarily to frequency or phase variations and is insensitive to amplitude variations, it will give normal reception of a frequency modulated or phase modulated signal but noise will be greatly reduced. Hence in a F.M. or P.M. system there is large gain in signal to noise ratio, as compared to an A.M.

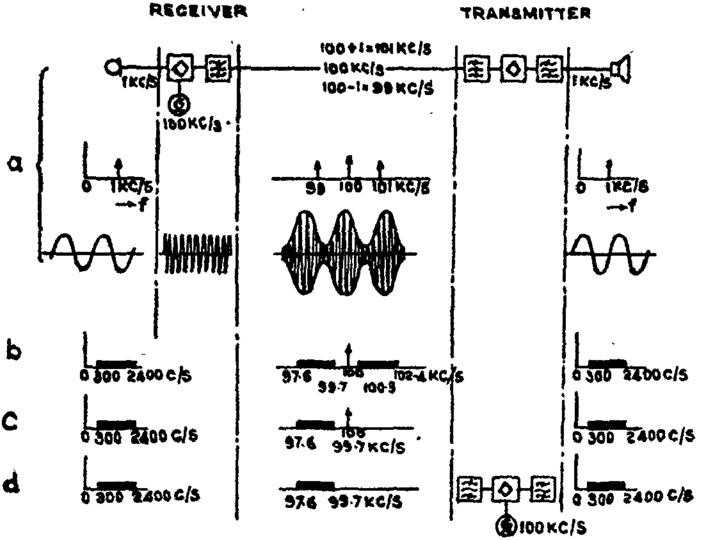


FIG. 6. PRINCIPLE DIAGRAM OF AMPLITUDE MODULATION.

a. General principle of amplitude modulation
b. Transmission of carrier frequency with higher and lower side bands.
c. Transmission of carrier frequency and lower side band.
d. Transmission of lower side band only and demodulation by addition of the carrier frequency in the receiver station.

system. However, this gain depends on the strength of the received signal, the character of the noise and the way the noise is distributed over the receiver passband.

(3) Unlike in the case of amplitude modulation where for a single modulating frequency, there is only one pair of side-band components in the modulated wave, in the frequency modulation and phase modulation systems an infinite number of pairs of side-band components are produced. These side-band pairs are spaced in the spectrum above and below the carrier frequency as multiples of the audio-frequency. The first side-band pair occurs at carrier plus audio frequency and carrier minus audio frequency. The second pair occurs at carrier plus twice the audio frequency and carrier minus twice the audio frequency and so on. Hence the channel width required for a frequency modulated system is much greater than the channel width required in an amplitude modulated system. Whatever gain in signal to noise ratio is obtained in the F.M.

or P.M. System it is at the expense of channel width.

(4) Assuming the same unmodulated carrier power in all cases, a narrow band F.M. or P.M. System is not as effective as Amplitude modulation system. So far as effectiveness is concerned the narrow band F.M. or P.M. transmitter is about equivalent to a 100 per cent modulated A.M. transmitter operating at one fourth the power input.

Hence amplitude modulation is the most commonly used system of modulation.

10. *Comparison of the different systems of transmission.*—The different systems of transmission have been enumerated already.

It was mentioned earlier that the power in the side-bands is 25 per cent of the carrier power and the total power of a modulated wave is 1½ times the carrier power. It is therefore obvious that 2/3rd of the total power of a 100 per cent modulated wave is in the carrier, the transmission of which adds nothing to the intelligence received. Hence if one side-band alone is transmitted (the carrier being supressed) having sufficient power to give an acoustic signal equal to that given by a carrier and both side-bands, it can be shown that the single side-band transmitter will consume about two-thirds of the power, compared to a similar transmitter transmitting both side-bands and the carrier, on the assumption that the modulation is 100 per cent. It can also be shown that the elimination of the carrier is equivalent to increasing the transmitter power eight times. The single side-band transmission has the following advantages.

(1) Reduction in channel width as only one side-band is transmitted.

(2) Gain in signal to noise ratio due to reduction in channel width and substitution of the carrier at the receiver, as the received noise frequency is only half as broad as in a double side-band system. Besides, as the carrier is not transmitted the whole transmission power is put into the single side-band which alone represents the signal. Hence there is a large gain in signal to noise ratio.

(3) The elimination of the carrier makes possible the repetition of the carrier frequencies for some applications (such as telemetering etc.) and further increases the gain in channel space .

The single side-band system on account of the additional equipment required for suppressing one of the side-bands and the carrier and for substituting the carrier at the receiving end is much costlier than the double side-band system of transmission. Hence the single side-band system is used only where there is overcrowding of the frequency spectrum and gain in channel width is required. This system is also used for very high voltage lines of 220 KV and above, where the distance between stations is very long and consequently the attenuation (or power loss along the line) is very great. Besides in very high voltage lines, the corona effect is considerably large and gives rise to additional disturbances. Hence lines of 220 KV and above have

considerably higher noise level than lines with lower voltage. As the whole of the transmission power is put into the signal in the single side-band system, this system is used for 220 KV lines and above, which have a high noise-level.

In the single side-band carrier suppressed system it is of utmost importance that the carrier is reproduced at the receiver correctly, with an error of only ± a few cycles per second which is a little difficult.

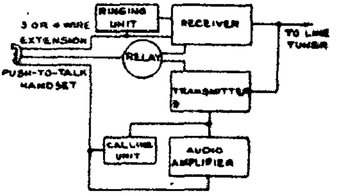
The system of transmitting both side-bands with carrier suppressed, is not generally adopted, as it has no relative distinct advantages over the other systems, notwithstanding the difficulty of replacing the carrier correctly at the receiving end.

The transmission of one side-band with carrier, no doubt avoids the somewhat difficult operation of replacing the carrier correctly at the receiving end. But the gain in power or signal strength is not much, as the major portion of the total power is required for transmitting the carrier itself. Hence this system is also not used very much. In such cases transmission of single side-band with a certain percentage of the carrier is adopted.

In a country which is in its initial stage of power line carrier development, where there is no danger of overcrowding of the carrier frequency spectrum, the amplitude modulation system, with double side-band is best suited in view of the economy in first cost and also the advantage of flexibility of this system for being converted into the single side-band system at a later stage by the addition of suitable single side-band panel units (at a little extra cost) if necessary to cope up with the crowding of the carrier frequency spectrum. Such a thing is not possible in the case of a frequency modulated system.

11. *Carrier communication system.*—There are two methods of communication viz., the Simplex and the Duplex and each one has its own field of application depending upon the nature of service and the expenditure that could be incurred.

12. *Simplex system.*—In the Simplex system only one carrier frequency is employed both for transmission and reception. Therefore transmission can proceed from one station only at a given instant and simultaneous conversation is not possible as the transmitter blocks the local receiver. In a manually operated Simplex system, a "push to talk" button is necessary on the telephone hand set as shown in Fig. 7 to enable the transmitter to be connected to the line. This system is the simplest one involving minimum equipment and cost. Where



BASIC UNITS OF MANUAL SIMPLEX COMMUNICATION ASSEMBLY WITH CODE-BELL CALLING

FIG. 7

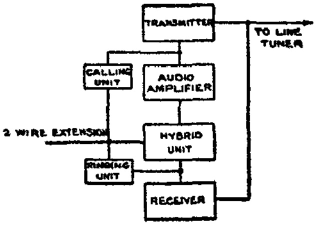
crowding of the frequency spectrum is a serious problem this system is adopted as it uses only one frequency channel at all the transmitting points.

In the automatic Simplex System the " push to talk " operation which is generally irksome is replaced by an electronic transfer unit which switches the equipment automatically to transmit or receive position as required. The switching is so rapid and quiet and is made between every slight pause or even between words that the user will not be able to detect its functioning and the speech can be interrupted. This is done as follows :—

The transmitting audio amplifier when there is a pause in speech is in the standby condition, it is unblocked and ready to amplify voice signals received from the telephone line. Reception of a carrier signal blocks the amplifier so that once reception has started no transmission can occur until the equipment returns to the standby condition. The electronic transfer unit switches automatically from standby condition to transmit or receive as required.

This automatic feature permits a single conversation among several stations on the channel and also it can be operated with two wire telephone extensions and through PBX boards without requiring any balancing or hybrid unit.

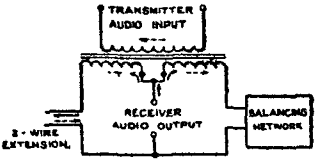
13. *Duplex system.*—In this system, transmission can take place simultaneously from both stations as in ordinary telephone service. This employs two frequencies one for transmission and the other for reception. The basic units of a two frequency duplex assembly are shown in Fig. 8. Apart from the fact that the transmitter and receiver operate on different frequencies this incorporates the audio hybrid unit for connecting up the two line or speech wires from the telephone switch board to the carrier frequency equipment.



BASIC UNITS OF TWO-FREQUENCY DUPLEX COMMUNICATION ASSEMBLY WITH CODE-BELL CALLING
FIG 8.

Without the hybrid unit if the telephone lines are connected directly to the carrier set the audio output of the receiver would feed into audio amplifier and would modulate the transmitter output. This would cause an audio howl which will make communication impossible.

A hybrid unit consisting of a differential transformer shown in Fig. 9 is necessary to link up the two wire telephone line with the four wire line represented by the two directional carrier frequency



TYPICAL HYBRID COIL AND CONNECTIONS THE COMPONENTS OF THE BALANCING NETWORK ARE CHOSEN TO MATCH THE INPUT IMPEDANCE OF THE TELEPHONE EXTENSION AS NEARLY AS POSSIBLE OVER THE VOICE - FREQUENCY BAND.
FIG. 9.

channel. This transfers the speech currents from the telephone switch board to the carrier frequency transmitter and from the carrier frequency receiver to the switch board respectively and during this process prevents the speech currents received from entering the transmitter at too large a level.

It is therefore essential that telephone extensions used with duplex assemblies be properly terminated and be free from discontinuity.

The determination of the proper balancing net work and adjustment of audio levels after installation are the important problems connected with the two frequency duplex equipment. The volume control and low frequency filters limit the speech band to 300–2,400 c/s. The transmitter side of the hybrid equipment includes also an amplitude limiter which automatically cuts off the voltage peaks of too loud a speech which might overcharge the channel and thus produce disturbances between transmitted signals.

14. *Wave change and fixed frequency system.*—Under the duplex two-frequency operation there are two systems of carrier telephony in operation, viz., the wave change or frequency change over system and the fixed frequency system.

15. *Wave change over system.*—In this case the transmitters and receivers of all the stations in the channel shown in Fig. 10 are initially turned to one of the two frequencies f_1 or f_2. Let us assume that they are tuned to frequency f_1. If station B wants to call station D, as soon as B lifts the telephone handset its transmitting frequency is f_1 and the receiving frequency is automatically changed to f_2. When the call is received at the Station D the transmitter frequency of that station is changed over to f_2 and its receiving frequency remains as f_1. The caller receives the normal ringing tone and the duplex channel between B and D is established. During the call the line remains blocked for the remaining stations and on lifting their handsets they obtain the busy tone.

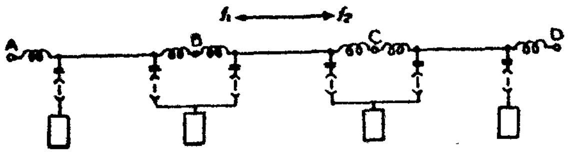


FIG. 10. DIAGRAM OF CARRIER TELEPHONY LINK BASED ON THE FREQUENCY CHANGE-OVER SYSTEM

Each station requires only one unit. Only one pair of frequencies is necessary for the whole system.

A, B, C, D = Generating or sub-stations

f_1, f_2 = Frequencies.

16. *Fixed frequency system.*—In this system different pairs of carrier frequencies are employed between two stations as shown in Fig. 11.

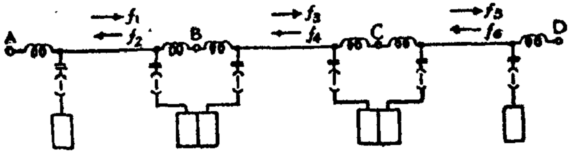


FIG. 11. DIAGRAM OF A CARRIER TELEPHONY LINK BASED ON THE FIXED FREQUENCY SYSTEM

Each intermediate station contains two units. One pair of frequencies is necessary per line section

A, B, C, D = Generating or sub-stations

f_1, f_2; f_3, f_4; f_5, f_6 = Pairs of frequencies

Each of the sections A-B-C-D- is fitted with a pair of carrier equipment and operates on a pair of frequencies f_3–f_4 and f_3–f_4, etc. The transmitter and receiver of an intermediate station for sections on either side are linked. Consider a call from Station A to Station C. Carrier frequency f_1 is generated and modulated with speech (audio) frequency at the station A and is received and demodulated in the corresponding receiver in the intermediate station B. It is then retransmitted after remodulation at Station B with the carrier frequency f_3 to station C and communication between A and C is established.

17. *Comparison between wave change and fixed frequency system.—Cost.*—The wave change system is cheaper than the fixed frequency system as it involves only one instead of two carrier set for intermediate stations.

Frequencies.—One pair of frequency for each wave change district of 4 or 5 intermediate stations will do instead of as many pairs of frequencies as there are sections in the fixed frequency system ; hence many carrier channels and stations can be accommodated within the allotted frequency range if wave change system is adopted.

Quality of reception.—As there is no amplification in the intermediate station in the wave change system the attenuation is greater and the audibility will be less. In the case of fixed frequency system because of intermediate amplification, a constant level of reception can be had though a certain amount of distortion will also be there because of demodulation and remodulation at every intermediate station.

Simultaneous calls.—When the end stations are engaged, intermediate stations cannot converse in both the systems. However in the case of fixed frequency system simultaneous conversation between sections is possible which cannot be had in the wave change system.

Transmission of signals.—In the case of fixed frequency system it is possible to use the same carrier set for transmission of speech and other signals using suitable filters. In the case of wave change system however as the transmitting and receiving frequencies constantly change with telephone calls it is not possible to combine with the telephone communication, the transmission of other signals like telemetering, relaying supervisory control, etc., which are continuous. Therefore, separate carrier sets for communication and other facilities have to be employed in the wave change system.

General.—In the case of wave change system, intermediate stations can be introduced without difficulty, whereas in the fixed frequency system shifting of the carrier sets of any one of the stations on either side will have to be done. Further any trouble in the intermediate station of a wave change district, will not affect through communication as the affected set can be kept disconnected. In the case of fixed frequency any trouble in an intermediate station will affect the through communication.

The choice of the systems, viz., fixed frequency or wave change will depend upon the ultimate number of stations, to be served, the possible channels to be allowed for, adequacy of the frequency range, the nature

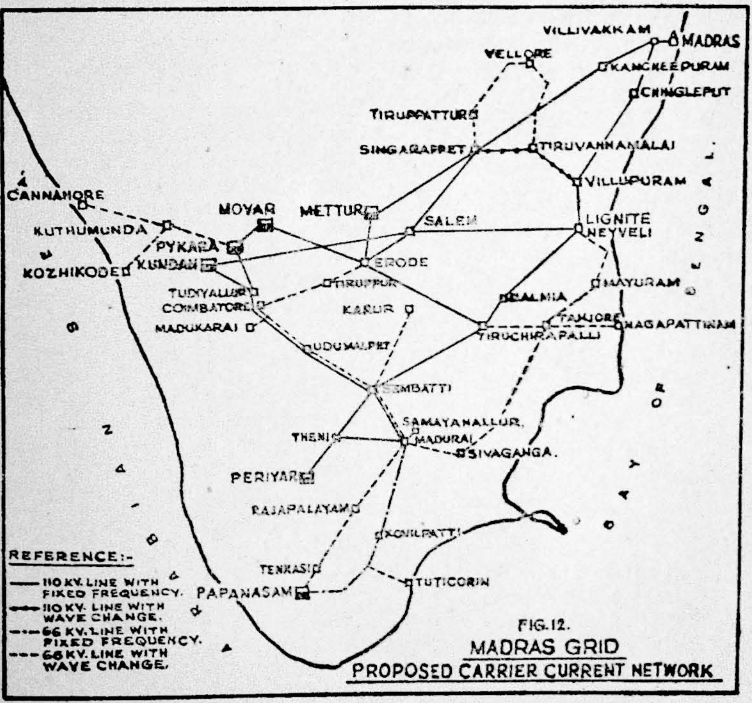


FIG. 12.
MADRAS GRID
PROPOSED CARRIER CURRENT NETWORK

of the service required and other facilities to be provided. It would appear desirable to have fixed frequency system on important sections and wave change system on unimportant ones. A suggested scheme for the future Madras Grid is indicated in Figure 12. It may be seen that the loops that are formed in different sections will provide alternate paths for the calls to go through and thereby increase the traffic handling capacity of the system. By providing additional channels in some of the sections the capacity for communication can be further increased. For instance, a call from Madras to Papanasam can go through Singarappet-Erode-Pykara Sembatti-Madura or through Neiveli - Tiruchirapalli - Sembatti - Madura, with further alterantive paths through other loops on the way. If an additional channel is provided for Madras-Villivakkam section it will clear the bottleneck in this section.

18. *Telephone exchange.*—The carrier set can be connected to the local manual or automatic exchange board through connecting links or relays. By means of two way units magneto telephone lines can also be connected to the carrier system. The number of simultaneous conversations possible through the exchange depends on the number of connecting relays. If there are two connecting relays to two carrier sets and one for local connections then there can be two outside and one local call at the same time. At a time when there is no outside call all the three connecting relays can be used for the local calls.

19. *Calling systems.*—Many methods of establishing a call over the carrier channel are in use, the important of them being code-bell calling, voice calling, automatic bell calling and dial selective calling. The dial selective calling is the best in which other special features like busy signal, revertive or ringing back signal, local inter-communication, executive right of way or priority service and disconnect signal can be incorporated. For instance if the wanted subscriber is engaged, the call is automatically routed to a special telephone set which may be an attended one, or calls may be transferred internally to some other person to attend. Such additional facilities will enable distant calls not being wasted.

20. *Other facilities.*—Power line carrier is invariably used for other purposes like Relaying, Telemetering and Supervisory control also. When mere telephone communication is needed uni-purpose carrier set with a band width of 5 Kc. is used for double side band transmission of speech. When telephony is combined with telemetering, relaying, etc., multi purpose carrier set with a band width of 8 Kc. is used to accommodate the several A.F. channels mentioned in the para dealing with frequency range.

The extra cost involved for purpose of introducing these facilities is towards the cost of installing A.F. transmitters and receivers for translating the meter readings which are electrical quantities to A.F. pulses to modulate the carrier and vice versa.

The two telemetering channels 2,770 to 3,230 c/s and 3,450 to 3,950 c/s with a band width of about 500 c/s can transmit 8 values

with a spacing of 120 c/s. As too many channels will affect the transmission level for a given carrier output it is some-times advantageous to adopt cyclic switching for reducing the number of channels used at the same time and increasing the number of values transmitted. By cyclic switching a maximum of 16 values can be switched in an interval of 3 seconds. By using two channels 32 values can be transmitted.

In case continuous transmission of a large number of values say more than five is necessary, then a separate carrier set will have to be used for telemetering. In a band width of 2·5 Kc about 18 values can be transmitted. Under such conditions uni-purpose carrier set of 5 Kc/s for communication and another set of 2·5 Kc/s for telemetering may be used and there will be slight saving in frequency range as the total range utilized will be only 12·5 instead of 16 Kc. in the case of multi-purpose carrier set for the reason that the carrier set for telemetering need operate only in one direction while that for communication purposes operates in both the directions.

Separate carrier sets for communication and other facilities enable their use both in the fixed frequency and wave change systems while the multi purpose carrier set can be used only in the fixed frequency system.

Several carrier channels can function on the same power line making joint use of the coupling and tuning equipment. Such combined use enables an investment on additional facilities which might not be justifiable for a single function alone.

21. *Conclusion.*—After a detailed study, the Department has decided to adopt amplitude modulation with double side band transmission and duplex system of communication for the Madras Grid. Multipurpose carrier set of 8 kc/s band width will be used with fixed frequency system for the sections where carrier communication is proposed to be introduced now so that besides communication we may have in due course telemetering with load despatching centre located at Erode and also relaying for some of the sections of transmission lines.

20 DEC 1955

Progress During the Quarter Ending 31st December 1954

Construction Branch

Pykara Plant Extensions, III stage.—Masonry work in the main dam in the overflow section was in progress. Concreting the R.C.C. core wall and R.C.C. Diaphragm wall was completed. Erection of power and outlet pipes with their valves was completed. Masonry in upstream and downstream wing wall was completed.

Mathurai Thermal Scheme.—The construction of additional quarters was completed. Laying of 6-inch diameter pipe line for cooling water make up was taken up.

Madras Plant Extensions.—Under the I stage extensions, the official acceptance tests on the 15 M.W. turbo set were conducted satisfactorily.

Under the II stage extensions, all the piles for the boiler No. 5 have been driven and concreted. Tests have been conducted on five piles. The trial run of the 15 M.W. turbo alternator set was conducted satisfactorily on 21st December 1954 and arrangements were in progress for running the set, for drying the unit and conducting high voltage tests, etc., before commissioning. The hydraulic test and dry survey of the boiler No. 1 was completed by the Boiler Inspector.

Periyar Hydro Electric Scheme.—Settlement with the Travancore-Cochin Government was reached regarding the royalty to be paid and the administrative approval of Government was received in November 1954. Specifications for step-up transformers and transmission lines have been issued. Tenders for the construction of buildings in lower camp area have been called for. Pitching up tents and jungle clearance were progressing. Temporary sheds were being erected. Land acquisition proposals for lower camp were sent to the Revenue Department.

Transmission Lines and Sub-stations.—(i) *Erode Sub-station.*—Contract has been awarded for the construction of mulsifyre installation pressure tank house. Concreting the foundation of repair house was completed and erection of stanchions was in progress.

(ii) *Salem-Namakkal* 110 *KV line.*—Check survey and excavation in the Rasipuram-Namakkal section was in progress.

(iii) *Singarappet-Villupuram* 110 *KV. S.C. line* (68.6 *miles*).—Reconnaissance survey and theodolite alignment, chain survey, and inspection of site to study the suitability for tower locations have been completed.

(iv) *Singarappet-Vellore* 66 *KV 2nd circuit* (73 *miles*).—Chain survey and levelling for about 50 miles have been completed.

(v) *South Kanara Scheme.*—In the Hulikal-Mangalore section jungle clearance, check survey, excavation and stub-setting and erection of towers were completed. Earthing of towers 73 per cent, hoisting insulators, 98 per cent, stringing of power conductors and earth wire 99·5 per cent were completed. In the Udipi-Karkala section, jungle clearance and check survey were completed. Works relating to excavation of pits, earthing and painting of poles were in various stages of progress. In the Udipi-Coondapoor section, jungle clearance, pegging out pole locations and erection of poles were in various stages of progress.

(vi) *Pykara-Coimbatore-Madurai 110 KV line.*—Works in respect of Coimbatore-Madurai section of this 110 KV line were over. Under the Pykara-Coimbatore section of this line, tree clearance, excavation, concreting, tower erection, earthing and stringing of conductors and earthwire, providing of boulder protection in Adderly slopes and erection of switches for the switching tower were completed.

OPERATING SYSTEMS

Hydro Systems—Generation

The station peak load, units generated and the system peak load, were, as follows :—

Name of system/station.	*Station peak load in MW.*	*Units generated in millions.*	*System peak load in MW.*
Pykara	54·9	54·65 }	59·800
Moyar	35·6	23·32 }	
Mettur	45·5	85·56	58·400
Papanasam	28·0	24·80 }	25·0
Madurai Thermal	10·0	7·55 }	
Udipi	222 K.W.	..	222 K.W.
Karkala	42 K.W.	..	42 K.W.

The following services were connected during the quarter :

	Agricultural.	*Industrial.*	*Domestic.*
Pykara	198	21	1,331 + 8 street lighting.
Mettur	229	17	906
Papanasam	123	13	1,213

The water position in Mukurti, Pykara, Mettur and Papanasam reservoirs was satisfactory during the quarter. However, the inflows at Papanasam Reservoir during November and first half of December 1954 were poor necessitating full thermal relief from Madras and Madurai thermal stations.

Distribution

Pykara Electricity System.—Works relating to the establishment of permanent sub-stations at Pollachi and Nagamam were continued. About 90 per cent of the 33 KV line extensions from Puliampatti to Shenbagapudur was completed. The Kollengode extensions involving 6·2 miles of H.T. 22 KV single circuit and 12·6 miles of L.T. lines and six distribution transformers were energised on 19th October 1954. Works on Alathur and Tirur-Ponnani extensions were in advanced stage of construction. The Katpadi extension in Udipi area were completed and energised.

Extension of 22 KV lines from Cumbum to Periyar in connection with the Periyar Project was taken up.

Electric supply was extended to 28 villages during the quarter.

Mettur Electricity System.—The total outturn of the Mettur workshops during the quarter was to the value of Rs. 6·56 lakhs.

At Tiruvannamalai sub-station the two 1250 KVA. B.T.H. transformers were put in service on the 33 KV side and one released 1000 KVA transformer was put in service on 11 KV side.

A 2500 KVA booster was commissioned at Villupuram sub-station on 13th November 1954.

Supply to the enclaves of Pondicherry was resumed from 3rd November 1954 and to Pondicherry proper from 13th November 1954.

Five villages were given electric supply during the quarter.

Papanasam Electricity System.—The 22 KV. G.E.C. Kiosk to control the Madurai-Sivaganga 22 KV feeder was commissioned at Sivaganga on 14th November 1954. One of the 1,000 KVA transformers at Kovilpatti was reconditioned. The Srivaikuntam 33 KV line was charged at 11 KV on 1st October 1954 to give supply to Srivaikuntam, etc. Sixteen villages were electrified during the quarter.

Thermal System.

Madras Electricity System.—The station peak load, units generated and systen peak load were as follows :—

Name of station.	*Station peak load in MW.*	*Units generated in millions.*	*System peak load in MW.*
'A' Station	22·6	22·78	35·5
'B' Station	15·0	16·76	
'C' Station	2·2	0·58	

Three hundred and nine D.C. services with connected load of 354·79 K.W. were changed over to A. C.

Seventy-four agricultural services, 65 industrial services and 1,037 domestric services were connected during the quarter.

'B' *Station.*—The erection of boiler No. 1 under the 2nd stage was completed and the boiler was put on range.

'C' *Station.*—Eight villages were electrified during the quarter.

Accounts Branch

The Department earned a revenue of Rs. 150·56 lakhs during this quarter and the working expenses amounted to Rs. 92·56 lakhs. The capital expenditure amounted to Rs. 95·38 lakhs.

Technical Branch

(*a*) *Civil.*—The following were some of the more important works attended to during the quarter :—

Contract was awarded to Coromandal Engineering Co. for work ; on foundation slab under Madras Plant Extensions, II Stage.

Sealed tenders were called for the supply and erection of cooling plant to suit the installation of generating machinery of 30 M.W. capacity under Madras III stage.

Work on Periyar hydro-electric scheme was being put on hand for power tunnel and surge shaft design calculations, drawings and specifications were finalised.

Collection and compilation of rainfall and run off of various basins in the State were continued.

Hydro-metric Surveys Division opened a new section in the Electricity Department stall on Hydrology showing the various instruments used in Hydro-metric survey works in Teynampet Congress grounds.

(*b*) *Electrical.*—The following were some of the more important works attended to during the quarter :—

For Singarapet-Villupuram 110 KV and Singarapet-Vellore 66 KV lines an order for heavy sized leg members for the towers was placed with Messrs. Jessops & Co., Calcutta.

Tower drawings for the 66 KV lines from Madukarai tapping point to Madukarai sub-station for the Coimbatore-Madukarai-Palghat 66 KV extensions were sent for fabrication of towers.

Quotations for control cables required for South Madras sub-stations under specification E.169 were invited, analysed and orders were placed.

Under the Madras Plant extensions, tenders for third stage plant and machinery called for by Director General, Supplies and Disposals, under the Indo-U.S. Aid programme, issued by the Director General, India Store Department, were being analysed.

Forty-nine orders on different firms for meters, A.C.S.R. and copper conductors, transformers, pipes poles, lightning arresters, A.B. switches, second-hand rails, H.T. insulators, etc., were issued.

Tentative designs for various types of towers have been worked out and steel required has been ordered.

In connection with the ensuing All-India Congress Exhibition, 1955, at Teynampet, in which the Electricity Department is taking part re-erection of models at the Exhibition grounds was in rapid progress.

Instructions for the use, inspection and testing of "Electricians Rubber Gloves" and certain modifications to the existing instructions on the "Co-ordination of line and sub-station insulation" were issued.

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The Government Electricity Department in 1953—54

(Abstracts from the Administration Report.)

The aggregate of the power demands on the Government systems was 151,924 KW. and the units generated 758·71 millions. Details for the various systems are given below :—

Name of system.	Power demand in K.W.	Generation in millions of units.
I. Hydro-electric—		
Pykara	50,200	199·4880 +85·9020 (Moyar)
Mettur	48,300	193·2772
Papanasam	22,300	98·1783 +27·5086 (Madurai thermal station).
II. Thermal (steam)—		
Madras	30,600	152·9980
III. Thermal (diesel)—		
Udipi	212	0·4532
Karkala	36	0·0650
IV Power purchased from Mysore and other sources—		
Kollegal	176	0·5605
Fort Cochin	100	0·2805
Total ..	151,924	758·7113

Figures for power generation in the State from all sources were as follows :—

Source of generation.	Generation in millions of units.
Government—	
Hydro-electric	576·85
Thermal (steam)	180·51
Thermal (diesel)	0·52
Purchased from Mysore and other sources.	0·84
Licensees (thermal)	3·84
Total ..	762·56

It would be seen from the above that almost the entire power generation in the State was by the Department.

The total generation in the State was 762·56 million units as against 705·43 million units in the area comprised in the present Madras State in 1952–53.

The power generated was utilized as under :—

Use	*Percentage of total power utilized.*
Industrial supplies	53
Irrigation and agriculture	15
Domestic heat, power, lights and fans ..	14
Commercial heat, power, lights and fans ..	6
Public lighting	2·5
Traction	2
Miscellaneous	2·5
Total ..	100

Load development.—The demand for power for industrial and agricultural purposes continued to be on the increase. In view of the paucity of funds, shortage of generating and transformer capacity, new supplies were confined to domestic, agricultural and a few essential industries.

Financial results.—The gross revenue earned by the Departmental undertakings in operation during 1953–54 was Rs. 481 lakhs as against Rs. 431 lakhs in 1952–53 in the present Madras State registering an increase of 11·6 per cent. Details of capital outlay, gross revenue, working expenses and net revenue of the systems are furnished hereunder :—

Name of system.	*Year of operation.*	*Total capital outlay.*	*Gross revenue.*	*Total working expenses.*	*Net revenue.*
I Hydro-electric schemes—					
Pykara	Twenty-first ..	976·11	139·31	61·28	78·03
Mettur	Seventeenth ..	628·82	110·01	67·22	42·79
Papanasam ..	Tenth ..	524·56	57·74	46·90	10·84
II Thermal—					
Madras	Seventh ..	779·65	173·45	135·54	37·91
	Total	2,909·14	480·51	310·94	169·57

The return on capital outlay in operating systems works out to 5·8 per cent net.

The receipts from the Inspectorate amounted to Rs. 11·39 lakhs made up of Rs. 10·20 lakhs from the electricity duty, Rs. 0·91 lakhs from inspections under the Indian Electricity Act and Cinematograph Act, Rs. 0·20 lakhs from royalty for use of Government water for generation of electricity and Rs. 0·08 lakhs from fees for audit of licensees' accounts.

Number of consumers.—There were 341,854 consumers at the end of 1953–54 served by all electrical undertakings in the State including Government areas.

Of these 337,208 consumers were in the areas served by power generated from *Government undertakings*: 164,778 being served directly by the Electricity Department and the rest 172,430 by licensees distributing Government power. The balance of consumers, viz., 4,646 were served by self-generating licensees. Details are given below :—

Name of system.	*Number of consumers.* Served by the Electricity Department.	Served through licensees in Government areas.
Hydro-electric—		
Pykara	50,103	26,879
Mettur	27,655	102,417
Papanasam	35,783	41,794
Thermal—		
Madras	50,694	1,340
Power purchased from outside—		
Kollegal	543	
Total ..	164,778	172,430
Other licensees	4,646	
Total ..	3,41,854	

Supply was extended to 71 villages and towns by the Department and to 49 villages and towns by the licensees during the year. The total number of villages and townships having electric supply at the end of 1953–54 was 2,089 and 293 respectively. Of these 1,402 were served by the Electricity Department and the rest by licensees.

Transmission lines and sub-stations.—The route mileage of Government transmission and distribution net work increased by 762 miles

during the year. The total miles of high tension and low tension lines in each system at the end of the year are furnished hereunder :—

Name of system.	*Number of route miles.* H.T.	L.T.	*Total.*
Pykara	1,922	2,447	4,369
Mettur	1,783	1,229	3,102
Papanasam	809	699	1,508
Madras	477	763	1,240
Generation Circle, Erode ..	428	Nil	428
Total ..	5,419	5,138	10,557

Details of E.H.T. and H.T. transformer stations are as below :—

System.	*66 and 110 KV* Number.	*Capacity. KVA*	*22 and 33 KV* Number.	*Capacity. K.V.A.*
Pykara	13	91,250	2	1,750
Mettur	18	103,250	8	11,500
Papanasam	8	34,500	5	14,250
Madras	2	23,000	15	24,350
Total.	41	252,000	30	51,850

NOTE.—This does not include transformers in power-houses.

Agricultural development.—Top priority was continued to be given in the matter of giving supply to agricultural loads with a view to aid the Grow More Food Campaign. However, due to restricted budget provision in the first-half of the year, services were extended only to those who gave voluntary loans. The position became normal during the second-half of the year. During the year 1,030 agricultural pump-sets were connected up by the Department and 579 by licensees. Details of agricultural services with their connected load in the different areas at the end of 1953–54 are given below :—

Name of the system.	*Number of services connected in 1953–54.*	*Connected load in KW*	*Total number of services at the end of the year.*	*Total connected load in KW. at the end of 1953–54.*
Pykara	495	2,078	8,560	38,007
Mettur	302	1,224	5,006	19,469
Papanasam	118	424	2,167	6,969
Madras	115	542	1,438	7,128
Total ..	1,030	4,268	17,171	71,573
Licensees distributing Government power.	579	2,962	4,562	19,209
Total ..	1,609	7,230	21,733	90,782

Rural welfare schemes.—Due to restriction of funds, no new scheme has been sanctioned under the Firka Development Scheme excepting a small scheme costing Rs. 22,000 for supplying power to five agricultural, 23 domestic and six street light services in the Papanasam System.

Construction activities.—Construction works connected with the Five-Year Plan of Power development in the State (excepting distribution of power) were in full swing and a total capital expenditure of Rs. 2·34 crores was incurred on major projects and transmission lines.

New schemes sanctioned.—The scheme for erection of a single circuit 110 KV line from Singarapet-Villupuram with 110/66 KV sub-station at Villupuram, a second circuit 66 KV line from Singarapet-Vellore and change over of the existing Tiruvannamalai-Arni line from 33 to 66 KV, linking of Arni and Vellore sub-stations costing Rs. 98·43 lakhs initially and rising to Rs. 107·72 lakhs utlimately was sanctioned during the year.

Electrical Inspectorate and Licensees.—The number of licensees undertakings at the close of the year was 30 of which seven were managed by local bodies and the rest by private companies. There was also one sanctioned operating under section 28 of the Indian Electricity Act. No new licences or extensions of period or area of existing licences were sanctioned.

In view of the difficult financial position, no loans were given to the licensees. Permission was granted under section 9 (2) of the Indian Electricity Act, to the South Arcot and Vellore Electric Licensees to take mortgage loans of 15 lakhs and Rs. 6 lakhs, respectively from the Madras Industrial Investment Corporation. The accounts of 23 licensees were audited by the Audit Officer and the staff appointed therefor.

There were at the end of the year 644 cinemas out of which 312 were permanent and 332 were temporary.

The total number of accidents during the year including those on lines owned and operated by Government was 214 of which 62 were fatal.

R. RAJAPPAN.

Letter to the Editor

Aluminium Cables

A good length of L.T. aluminium sheathed cables were laid during 1950–51 in the City of Madras as a trial measure. These conformed to the Departmental specification for cables for use in the Madras Electricity System having triple hessian tapes below and over the armour and a special preservative compound over the aluminium sheath as in the case of lead sheathed cables normally used in the Madras Electricity System. These cables were cheaper than equivalent lead sheathed cables by about 7 per cent. It has been later found that the performance of these aluminium cables has not been satisfactory, since even within a short period of their being put into use a number of failures in the cables were reported. Most of the faults were found to have developed in the through runs, the aluminium sheath and core being found burnt at points of fault. As such further cables of this type were not laid. But in view of the increasing use of such cables as reported in other countries and their greater cheapness I would like to know whether any other large Electricity Supply Systems in India have used these cables also, and if so, what their experience has been.

P. A. RAMAN.

Technical Press

Electricity Production and Consumption in India during 1953

Electricity sales.—During the year, 5,597 million kWh were sold to ultimate consumers out of which 4,704·1 million kWh were sold direct to ultimate consumers and the rest through distributing licensees. 86·5 million kWh were purchased from non-electric utilities and the corresponding sales are included in the total kWh sold to the ultimate consumers. Bombay contributed 1,822·8, Bengal 1,225·4, Madras 555·9, Mysore 505·0, Uttar Pradesh 488·4 million kWh respectively and the rest was contributed by other States and States Unions. During this year, the total energy sales registered an increase of 11·8 per cent over the 1952 sales as against a figure of 4·4 per cent increase in 1952 over 1951.

Consumer and Connected Load Data.—The total number of

consumers in India at the end of the calendar year 1953 was about 2 million having risen by 0·152 million over the previous year. These consumers had a total connected load of 3·621 million kW showing an increase of 0·168 million kW over the previous year.

Per Capita Consumption.—The *Per Capita* consumption of electricity varies from 0·49 to 77·91 kWh in different States and States Unions. Delhi has recorded the highest figure of 77·91, Mysore 55·65, Bombay 50·70, Bengal 49·29, Travancore-Cochin 16·4, Madras 15·23, Saurashtra 10·13, Punjab 9·66, Uttar Pradesh 7·73, Madhya Pradesh 5·3 kWh respectively and the rest below 5 kWh.

The average *Per Capita* consumption of electricity for the Indian Union was 15·47 (corresponding to 18·5 kWh of energy production) based on 1951 Census figure as compared with 13·83 for the previous year. If the generation of plants of industrial establishments and Railways is also taken into account the *Per Capita* consumption of electricity for the year would be about 24·3 kWh.

Capital Investment and Overall Revenue.—The total capital expenditure up to the end of the year 1952 on Public Electricity Supply Undertakings in the country amounts to Rs. 193·5 crores, which shows an increase of 14·4 per cent over that of the year 1951.

—"*Power Engineer*," January 1955.

Per Capita Electricity Production in Various Countries for 1953

Country.	*Per capita electricity production (kWh).*
Norway	5,698
Canada	4,431
Sweden	3,119
U.S.A.	2,771
Switzerland ..	2,282
New Zealand ..	1,674
Australia	1,467
U.K.	1,288
Finland	1,267
Belgium	1,117
Union of South Africa.	1,015
Austria	981
France	909
Italy	679
Netherlands ..	679
Japan	642
Denmark	537
Ireland	424
Spain	355
Chile	328
Argentina	268
Mexico	204
Brazil	55
Turkey	49
India	19

—"*Power Engineer*," January 1955.

Infinitely-variable Speed Regulation of Small output Electrical Machines.

The infinitely-variable speed regulation of small output electrical machines presents a number of difficulties and problems. For instance the regulation unit must be sturdy against which it must be as small as possible and handy to use.

Remembering the large number of uses to which it may be put in the home, workshop or laboratory, etc., full precautions must be taken to ensure that no accidental contact can be made with any electrically "live" parts.

Messrs. Rekofa, Rheinische Kohlenbuerstenfabrik Franz Wenzel KG. of Ahrweiler (Rhld.) have recently introduced a unit claimed as fully meeting all these requirements. The principle involved is based on a pressure-responsive alteration to the resistance of a pile built up of carbon wafers. Normally speaking such types of "pressure-responsive carbon regulators" are built into the current circuits of various machines with an output of up to some 80 watts and they are used to govern the speed from stop to the highest possible. Their main field of use is on sewing machine motors, dentists' drill motors, motors of pleating machines, winding machines, etc.

The speed regulator mentioned above is provided with wafers of carbon which as pressure is applied or released alter their resistance. The advantages to be obtained using carbon resistors instead of metal resistors have, to date, not been exceeded. At normal operating temperatures only a very minute degree of oxidization takes place on these resistors added to which the oxidation product is always gaseous providing that the carbon used is chemically pure and a coating of foreign substances is not used purposely. The carbon used by Messrs. Rheinische Kohlenbuerstenfabrik is quite pure. Absorbed oxidization gases have no effect whatever on pressure-responsive carbon regulators. Each regulator is provided with a large number of carbon wafers which, according to the proposed use are of varying thicknesses. According to the type of wafer being used and to the thickness of the individual wafers themselves, a certain amount of residual resistance is obtained after the maximum pressure is applied on the pile but this is bridged successfully by short-circuit contacts and will have little or no influence whatever on the speed.

—"*Der Export-Markt,*" M.23/1954.

Specialisation.

In his speech at the recent annual dinner of the Institution of Mechanical Engineers, Viscount Chandos commented most humorously, albeit truly, on specialization among engineers. It was so specialized that complete technical understanding between sections was impossible. Thus, a paper, say, on the aerofoil section and turbulent flow—bread and butter to the aeronautical engineer—may well be completely incomprehensible to the equally erudite and academically qualified engineer engaged on the design of switchgear. Similarly, a civil engineer who would quite confidently design a large bridge or dam may find himself confounded by a tiny transistor—the new plaything of the electronic engineer—hardly as big as a structural rivet. To exist today the engineer is forced to specialize, to some degree at least; obviously, the more involved and intimate the study, the greater must be the specialization. It is safe to say that there can be no such person

as a general practitioner in engineering. Probably a works engineer or a ship's engineer approaches this concept more nearly than others; even they must specialize, at least, in their own particular plant, and must get to know it thoroughly, though it includes many of the main branches of engineering.

The danger of the present mass withdrawal of engineers into their respective specialist shells is that, in many cases, they become out of touch with the overall scheme of industry. Thus we have the present tendency for the accountant—that financial wizard—to creep in and "run the show," usually at top management level; whilst at the other end of the scale the manual worker is "cracking the whip" as hard as he can.

We all realize that most concerns are run for the twin purposes of satisfying a consumer demand and making a profit for the shareholders. Only the nationalized industries appear to be altruistic enough to waive the profit and yet—let it be whispered—sometimes be not much troubled about the customer; no doubt these industries operate on the well-known Karno(F)-cycle, also known as the financial perpetual motion cycle, where admission and cut-off are governed solely by the treasury driven through a system of indirect gearing consisting of, the T.U.C., the parliamentary whips, and the tax-payer. But, in the main, profit is a main motive for production, and financial control must be exercised at all stages.

The engineer—be he ever so specialized—will appreciate the vital importance of complete co-operation with both administrator and artisan; this must not, however, degenerate into total subservience to both. After all the engineer is the "kind post" of industry; without him the whole fabric would collapse. He has the knowledge—perhaps "know-how" would express it better—that keeps things going, and he should never forget it. The power to retain some of the once-great kudos of the engineer—some is irrecoverably lost already—rests with the engineer alone.

—"*Power and Works Engineering*,"
January 1955.

Static Electricity used for Making Patterns.

Another highly interesting fact about modern-day finishing and dressing machines is the important place now occupied by those units and plants which use static electricity to impart patterns to textiles. This method of processing is by no means new or original but nevertheless only quite recently has it been possible to talk about its extensive and large-scale use. Nowadays, users are offered a range of machines which have overcome successfully all their "growing pains" and which give simply amazing results. The principle involved—incidentally the patterns which can be produced are almost unlimited in number—is the exploitation of a high-tension electric field through which short cut fibre particles are "shot" on to the material being patterned. The particles are either "shot" to cover the whole surface or in a pre-determined pattern and the effect obtained can be compared

favourably with plush or velvet. The whole is very uniform and the individual fibres are immovably fixed to the material acting as back ground. The adhesive agent used is washable and will even stand up to chemical cleaning.

—"*Der Export Markt*," M. 23/1954.

Power Plants.

By Prof. Dr. H. Netz.

In the power plant field it is interesting to note the importance now being attached to gas turbines so that it is no surprise to learn that quite a number of important companies have taken up the manufacture of these important machines. Both stationary and mobile plants are available. Preference seems to be given to the so-called hot-air design with open or closed circulation. Outputs in this case go as high as 30,000 kW.

In the I.C. engine field it is interesting to see how popular air-cooled types of all kinds are becoming. No doubt at all this method of cooling has a great number of not-to-be-disregarded advantages when used for certain kinds or types of work. Put in a nutshell, up to a maximum output of some 250 H.P. and where the maximum number of cylinders involved does not exceed twelve, an air-cooled type of plant can be used to carry out exactly the same work, as its water cooled counterpart. Nowadays fully mobile types of power units with outputs up to 100 H.P. and cooled solely by air are quite common.

—"*Der Export Markt*," M. 23, 1954.

India's First Cable Factory.

Owned and financed entirely by the Government of India, the Hindusthan Cables Factory at Rupnarayanpur 140 miles north-west of Calcutta, was formally opened by West Bengal's Chief Minister, Dr. B. C. Roy, on 26th December 1954. Situated in the industrial belt of Damodar Valley and built at a cost of Rs. 1·10 crores, the factory is expected to meet the needs of India's expanding communication network by producing in single-shift operation 500 miles of cable worth Rupees one crore per annum. The target output of 1,000 miles per year, which is also the estimated annual requirement of the country, is expected to be reached by 1958. India's present requirement of cables worth Rs. 1½ crores is met entirely by imports.

The need for the establishment in India of an economic unit of production of cables was felt more acutely with the envisaged expansion of communications in the Five-Year Plan. It was finally decided in 1951 to set up a factory with the technical assistance of some foreign manufacturers and the Government entered into an agreement with a British firm, Messrs. Standard Telephones & Cables, Limited, for bringing the factory into operation by 1954. The construction of the factory was begun early in 1952 and completed in about two years. The factory started production in September 1954, and has produced thirty miles of cables in the first two months. At present the factory will produce only subscriber cable, i.e., cable which is used for lines inside a city or town. It is hoped

in near future the factory will be in a position to supply the demand of the Posts and Telegraphs Department for the trunk lines also.

—"*Journal of Scientific and Industrial Research,*" February 1955.

For the Countryside.

The British Electricity Supply Industry as a whole will spend no less than £ 50 million over the next five years in taking electricity to rural areas.

Already some outlying rural communities, typical of the territory still awaiting electrification, have received supply, and electricity is transforming the lives of the people living in them.

From the point of view of the supply authority, it would not be an economic proposition to take electricity to such scattered communities except at a cost which few consumers would be prepared to pay, but the Electricity Supply Industry has decided that the responsibility for speeding electricity supplies to the rural areas shall be considered as a national matter—that is, for the industry as a whole, not limited to individual Area Boards. Therefore, people in small isolated rural areas will be able to have electricity at a very reasonable connection charge, provided only that there is sufficient assured public support for each project.

—"*British Electricity,*" February 1955.

Shortage of Engineers.

In a recent issue of the Electrical World Dr. R. H. Trytten, Director of the Office of Scientific Personnel of the National Research Council, was reported as saying at a meeting of the American Society of Mechanical Engineers in Milwaukee that America was rapidly falling behind Russia in the race to produce engineers. It seemed probable that the total number of trained engineers in Russia to-day was closely comparable to that in the United States and to accomplish this the Russians had increased the number of engineering graduates from 29,000 in 1948 to more than 50,000 in 1954. In contrast to this, the United States produced only 19,000 graduate engineers in 1954. Perhaps it would be too much to ask where Great Britain stands in relation to all this, since the number of technological personnel available in this country in proportion to the population is only about one third of that in the United States.

—"*Electrical Review,*" December 1954.

Every body in the world stands in an electro static field that is vertically gradiented. This field represents a positive potential difference of 200V from the head down to the feet.—"A. E. Knowlton. Electrical World," 31st May 1954.

Social and Personal

Sri G. Sundaram, part-time Consulting Engineer to Government (Electrical), has been granted leave for sixteen days from 1st April 1955.

Sri K. M. Kuruvilla, on return from leave, has been posted as Chief Electrical Inspector to Government *vice* Sri K. V. Karantha granted leave for 87 days from 27th April to 22nd July 1955, preparatory to retirement.

The following Assistant Engineers (Electrical) and Ex-Municipal Electrical Engineers have been promoted as Divisional Electrical Engineers :—

Sri I. S. A. Jesudian.
Sri A. D. Moreas.
Sri K. R. Radhakrishnan.

Sri H. Raghavendra Rao, Executive Engineer (Civil) has been promoted as Superintending Engineer and posted as Superintending Engineer, Periyar Hydro-Electric Scheme.

The following Assistant Engineers (Civil) have been promoted as Executive Engineers (Civil) :—

Sri V. T. Arasu.
Sri T. V. S. Warrier.
Sri G. Krishnan.

Appreciation.

On the eve of Sri E. Balakrishna Nair, Assistant Electrical Engineer, retiring from service on 24th March 1955 forenoon, the Chief Engineer for Electricity is pleased to place on record his appreciation of the long, able and devoted service rendered by Sri E. Balakrishna Nair to the Department. The good wishes of the Department go to him for his health and happiness in his retirement.

The Government Electricity Department Stall in the All-India Khadi, Swadeshi and Industrial Exhibition, 1955.